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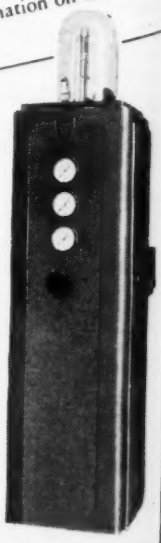

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Inconsistencies in Canadian Water Rate Structures

By William Storrie

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Presented on Apr. 8, 1946, at the Canadian Section Meeting, Niagara Falls, Ont., Can.

RATE structures in Canada generally appear to have been determined on almost every basis except the proper one—that of a fair and equitable return for the service rendered. Water customers should pay for service in accordance with its cost to the utility, which should be operated on recognized and sound business principles. Fire protection, street watering and sewer flushing should be paid for out of the general taxes. Free water to parks, public buildings and institutions should not be supplied unless due credit is indicated in the financial set-up of the system. The selling of water at rates below production costs, usually to entice industries to establish in the municipality, can only be done at the expense of other customers, and so cannot be justified.

The information contained in this paper has been secured from the *Water Works Information Exchange*, the Municipal Water Works By-Laws, in some cases direct from the municipal or utilities engineers and from the author's own experience. The water works systems in Canada are almost all publicly owned. The actual supervision and administration of these generally come under either a utilities commission, a committee of the municipal council or the council as a whole. Ontario has a much higher proportion of commissions than the other provinces. Frequently such commissions, particularly in Ontario, are charged also with the administration of electric systems and in a few instances with gas works systems.

Charges for domestic water supplies in Canada are divided into the usual two groups, flat rates and metered rates. The details for making these levies vary greatly with both types, and

much of this practice appears to be based on what is done elsewhere rather than on the actual cost of the service furnished.

A word of warning should be given in interpreting water rate schedules. To read in the *Water Works Information Exchange* that a municipality sells water to an outside municipality at the same rates as exist in the supplying municipality may be very misleading. For instance, the city of Cornwall sells water to the township of Cornwall at city rates. The population supplied in the township is almost as large as in the city. Over a 7-year period, the water works surplus was 33 per cent of the total revenue, none of which accrued to the benefit of the township customers. This 7-year surplus amounted to $182,000.

Again, when a rate of double the city rates is charged for supplying outside customers, it invariab'y applies to individual customers and not to the selling of water in bulk to outside areas.

Flat Rates

The methods of determining flat rate charges for water vary greatly. Many follow the same general principle of levying specific charges for such fixtures as sink or tap, bath, basin, toilet and laundry tub. A rate is set for the first of each of these in a residence and another for additional fixtures of the same kind. There appears to be little relationship between the charges made for the first of these units and the extra ones. They vary all the way from the same amount to a third or less. This discrepancy is less important, however, than the inequity inherent in the very use of the flat rate.

Several of the municipalities base their flat rates on the number of rooms in the house, as well as on the number of fixtures; some use the number of consumers. Such a basis necessitates a frequent check on the premises and the number of occupants, or the result will be inequitable charges.

Assessment of the premises as a means of determining the water rate is used in some municipalities. Hamilton, Kingston and Ottawa in Ontario all adhere to this practice. A somewhat modified procedure is prevalent in the province of Quebec where the annual rental of the property is assessed. Montreal employs such a method.

Rates which are based on assessment have the advantage of simplicity as compared with fixture rates, and they can be checked readily for any change without the necessity of a canvass of the premises. It can scarcely be expected, however, that assessment values will form any accurate index of the amount of water likely to be used on the premises.

The yearly charges made for the first tap or kitchen sink in different municipalities vary from $1.50 to $15.00; the average is about $6.00. The first bath is about $3.00, the first basin about $1.50 and the first toilet fixture about $4.00.

A separate scale of charges is set up for lawns and gardens. Some systems grade them according to area, others make one charge irrespective of area. Where sprinklers are used for lawn watering the rates are increased—usually doubled.

Building rates are generally based on the number of bricks, the amount of concrete, stone or plastering, and so on.

For commercial and business purposes, flat rates include a great number of different methods, depending on the number of employees, the business fixtures used, the number of machines,

etc. All of these are somewhat complicated and difficult of comparison with other rates. Where the assessment is used, the procedure, at least, is simplified.

A review of the methods used for the adjustment of water charges on a flat rate basis makes it apparent that there is no close uniformity among municipalities or the different services supplied. It becomes obvious that the flat rate cannot be equitable when it bears so little relation to the amount of water used or service rendered. That the trend in Canada is toward metering is a further indication of this defect. Where the source of supply is unlimited, as in the Great Lakes system, opinion as to the necessity of placing meters on residential customers is divided.

Metered Rates

In those centers where metered rates are in force, the situation is much more equitable. Provision is made for the rental of the meter either as a separate charge, or as a part of the minimum charge in the water bill. In some municipalities the meter is paid for outright by the property owner. Sliding rates, varying with the amount of water consumed during the billing period, are in general use. There are, to be sure, some exceptions, particularly in Toronto and Ottawa where the rates do not change with increased consumption. Complete lack of uniformity, however, governs dividing lines between the changes in the scale of rates. One municipality has at least 66 different meter rates, and most sliding scales consist of at least 12 variations in the rate.

The cost of water to the customer is not always the amount shown on the water bill. In Canadian municipalities, a number of other indirect charges are paid in taxes. Such taxes may cover a part of the capital costs, as well as fire protection costs and local improvement rates on mains.

The average cost for water works systems in Canada has been computed as $4.83 per capita per year, with debt charges amounting to 44 per cent of this total, or $2.14. These costs must serve as the basis for the rates to the customers. Similarly, the charges for water supplied have generally been between 8¢ and 15¢, with an average for a selected group of 13.75¢ per 1,000 gal. The two largest cities of the Dominion showed annual costs of $4.02 and $4.90 per capita, with the cost of water per 1,000 gal. the same, 11.7¢ for each.

Municipal Services and Fire Protection Charges

Public water supplies have a most important duty to perform in furnishing fire protection service. This service can be divided into two classes:

1. The "public service," or furnishing of an abundant supply of water at adequate pressure through hydrants attached to the distribution system.

2. The "private service," or supply of water in satisfactory quantity and pressure through hydrants or a sprinkler system connected with industrial or other large establishments.

Canadian practice in determining the basis of comparison for public fire protection service charges is wide and varied, with little or no attention given to ascertain what such service actually costs. What the traffic will bear has long been a controlling factor.

A study of the charges throughout Canada indicated in *Water Works Information Exchange* shows a wide

variation. On a hydrant rental, for example, costs vary all the way from no charge up to $231 per year, with an average of $40.42 per hydrant. Even on a per capita basis, the charge varies from nothing to $5.96 per capita per year, with an average of $0.46.

In Ontario, out of 91 municipalities reporting, 12 derive no revenue for fire protection purposes, 65 secure revenue on a hydrant rental basis and the remaining 14 on a basis other than hydrant rental. The average yearly rental per hydrant in Ontario is $38, ranging from $1.75 to $100. The average revenue for fire protection purposes in Ontario is 14.6 per cent of the total revenue received, ranging all the way from 0.06 to 43 per cent.

Inequalities in Existing Rate Structures

Some actual case histories will illustrate the wide variations in the rate structures of many Ontario municipalities.

1. In one year the revenue derived from fire protection in sixteen selected municipalities in Ontario amounted to $238,951, but the water works systems paid to the same municipalities for the reduction of the general tax rate the sum of $637,551, or $398,600 more than was received for fire protection.

2. In Ontario all publicly owned utilities are exempt from municipal taxes. In Calgary, Alta., a tax contribution of 5 per cent of the total water works revenue is paid by the water works system in lieu of municipal taxes. The amount of the tax bears no relation to the assessed value of the water works system but is purely an arbitrary figure set up by the city council. In Saskatoon, Sask., a similar tax is provided amounting to approximately 5 per cent of the water works revenue.

3. In Windsor, Ont., 1.5 mills on the assessed value of the property is charged for fire protection, in addition to a yearly rate of 6¢ per foot frontage on all vacant property owned by the city. These items amount to 22.6 per cent of the total water works revenue. The 1½ mills on all rateable assessment for fire protection purposes average $68.60 per hydrant.

4. At Peterborough, Ont., an annual sum equal to one-third the cost of operation (excluding the cost of water purification) is charged for fire protection services. This sum approximates 15 per cent of the total revenue.

5. The 28 cities in Ontario are equally divided between the use of the cubic foot and the gallon as the unit of measurement. In 52 other municipalities, 12 use the cubic foot and 40 the gallon. Combining these totals, we get 26 municipalities using the cubic foot unit and 54 using the gallon. One municipality in Ontario uses the U.S. gallon; all others use the Imperial gallon. It is interesting to note that eight municipalities own gas works systems in Ontario, and of course use the cubic foot as the basic unit for selling gas; they are equally divided between the use of the cubic foot and the gallon for water works purposes.

It is believed that the selling of water by the cubic foot came originally from the United States, where many of the water and gas supplies were owned by private companies which sold both water and gas on the same unit basis. In the early stages of water works development in Canada, most of the meters came from the United States, and therefore the cubic foot basis for metering water got a start in Canada.

6. In most municipalities no flat rate is charged for a horse or cow. In

about one-half of those reporting the rate is the same, and in the other half a horse is charged a rate double that for a cow. The rates vary all the way from 60¢ for a cow to $4.00 for a horse per year.

7. A dentist's chair varies all the way from $3.00 to $20.00; a chair in a barber shop ranges from $2.00 to $20.00. A soda fountain ranges from $2.50 to $30.00 and a bakery from $6.00 to $40.00, or from $1.50 to $6.00 per barrel of flour used daily. A photographer pays from $4.80 to $24.00, depending not on the volume of water used but only on the rates set up by the water works authority in his municipality. In one city a spittoon costs $3.60 yearly.

8. In another city, a traveling circus pays $25.00 per day for water, but if it is simply called a menagerie, water costs only $5.00 per day. In the same city, three railway companies are supplied with water at different rates of 12.0¢, 13.2¢ and 14.4¢ per 1,000 gal. All stores without a water service pay $7.20 yearly.

9. Average rates for building purposes vary all the way from 3¢ to 21¢ per 1,000 bricks, from 2½¢ to 15¢ per cubic yard of concrete and from 10¢ to 63¢ per 100 sq.yd. of plastering.

10. In Ottawa, metered customers must pay for water on the assessment basis if the amount of water used costs less at the standard meter rate than what would be paid on the assessment basis.

11. In 1931 the township of Teck (Kirkland Lake) entered into an agreement with several of the producing mines in that area to furnish water for mining purposes at a rate of 5½¢ per 1,000 gal. This rate was fixed on the assumption that the annual carrying charges on the debt created would be paid out of the tax rate. For the 10-year period ending in 1943, the six producing mines used 55 per cent of the total water pumped and paid 38 per cent of the total revenue received by the township from the sale of water.

During the 10-year period ending in 1943, the total revenue from the sale of water on the whole water works system amounted to 8.02¢ per 1,000 gal. and the total expenditure to 8.72¢ per 1,000 gal., a deficit of 0.70¢ per 1,000 gal., or $125,489.37 on the whole water works system.

During this period it cost the township 7.17¢ per 1,000 gal. to supply the producing mines with water, which the mines paid for at the rate of 5.53¢ per 1,000 gal. This meant a loss of 1.64¢ per 1,000 gal. to the township. At the same time, the other 210 metered customers in the township paid an average of 26.1¢ per 1,000 gal. In 1943 the six largest metered customers paid on the average 16.21¢ per 1,000 gal. All metered and unmetered customers in the township (excluding the mines) paid on the average 11.06¢ per 1,000 gal.

During the 10-year period, the cost of furnishing water to the mines resulted in an operating deficit of $141,843.23. The mines' share of the outstanding debt amounted to $158,755.84, or a total of $300,599.07. Five of the six producing mines paid up their share of all of the operating costs and some of the debt charges, and all together agreed to reimburse the township the sum of $274,098.48. There was no legal obligation for them to do so, but there was a moral obligation in that the basis arrived at for fixing the rate was wrong. It was wrong to the extent that, although the mines used 55 per cent of the total water pumped, they contributed only 6 per cent of the

total tax levy. In fixing the original rate at 5½¢ per 1,000 gal., it is quite apparent that the authorities overlooked the fact that mines cannot be taxed in the same manner as an ordinary industry. The only portion of the mines that could be placed on the tax levy was any office building or dwelling house situated on the mining property.

There are three important defects in the original agreement:

a. The mines were not compelled to take water from the township, although the township spent over $400,000 to furnish the mines with a supply.

b. No minimum quantity of water to be used by the mines was stipulated.

c. No provision was made for varying the rate to meet the constant yearly debt charges when greatly reduced quantities of water were used.

If the daily use of water by the mines had remained at 3 mil.gal., which was the maximum yearly average during the period of the agreement, then the 5½¢ rate would have almost covered all expenditures. In 1943, however, the daily average used by the mines was reduced to 1.62 mil.gal. There is evidence that the 5½¢ rate was based on an average daily consumption of 4 mil. gal., whereas the consumption over the 10-year period averaged 2.7 mil.gal., or 65.5 per cent of the contemplated quantity. The 1943 consumption was only 40.5 per cent of the contemplated quantity. In other words, the annual debt charges had to be spread over a much smaller quantity of water and therefore the debt charges per 1,000 gal. were substantially increased.

12. In 1922 the town of Timmins entered into an agreement with Hollinger Consolidated Gold Mines Ltd., whereby the Hollinger Mines undertook to supply water to Timmins "at cost." The agreement was badly drawn, very indefinite in its terms, lacked specific instructions as to how "cost" should be determined and omitted certain plans to which it nevertheless referred. The town assessed Hollinger for the water main passing through the town, and in a 20-year period the mine paid the town $208,368.42 in taxes, of which $69,249.95 was derived from the town through the water bills. The water passing through the Hollinger main situated in the streets of Timmins was sold not only to Timmins but to Schumacher and the McIntyre Mine. The question arose as to the right of Timmins to assess the mine. The water passing through the main was used only in part "for obtaining minerals from the ground." If it had been used solely for mining purposes, the town could not have assessed the mine. Since the mine sold water to Timmins, Schumacher and the McIntyre Mine, the Hollinger Mines placed themselves in the position of a private water company (in part at least) by selling water.

The agreement called for paying off the capital costs of installing the system over a period of 20 years. During this period, the maximum yearly average consumption was 3.95 mgd. in 1939. This dropped to 2.77 mgd. in 1944. The average daily consumption by Hollinger was reduced from a maximum of 2.57 mil.gal in 1936 to 1.24 mil.gal. in 1944. This caused the constant annual debt charges to be spread over a greatly reduced quantity of water, so that the rate paid by Timmins was increased from 4.604¢ per 1,000 gal. in 1937 to 7.120¢ in 1944. The annual debt charges have now been paid off, so that in 1945 the average rate was 4.783¢ per 1,000 gal.

13. One township with an average output of 2 mgd. sold 64 per cent of the total water pumped to an adjoining township for 17¢ per 1,000 gal.

Over a 4-year period it cost the township 17.4¢ to produce 1,000 gal. of water. The highest yearly cost was 19.4¢; the lowest, 15.5¢. This is an interesting case in that it paid the township to sell water at less than cost. The township had capacity available to supply its neighbor and so was able to spread the annual debt charges over a larger volume of water, thus reducing the cost per 1,000 gal.

Another township purchases water at 20¢ per 1,000 gal. and sells it to market gardeners at 18¢ per 1,000 gal.

14. The cost of producing water in 1943 in the 27 cities in Ontario varied from 2.2¢ to 16.3¢ per 1,000 gal. In the 117 towns in Ontario, the cost varied from 2.4¢ to 65.6¢ per 1,000 gal.

The daily consumption in Ontario in 1943 varied from 57 gal. to 180 gal. per capita in the cities and from 17 gal. to 550 gal. per capita in the towns.

In 1943 the 27 Ontario cities had a surplus of $1,724,531 or 18 per cent on a total revenue of $9,576,357. As far as can be ascertained, at least 12 per cent of the surplus was used for tax reduction purposes.

15. One town in Ontario is 86 per cent metered. The individual meters account for 57 per cent of the quantity pumped, as shown by the master meter.

One municipality sells water outside the municipal boundary at the city rates to industries but at double the city rates to domestic customers. Another city that sells water to outside customers at double the city rates has in recent years acquired a surplus of around 40 per cent of the revenue. Instead of reducing the rates, so-called "free water" is given during a part of each year, and thus the practice of charging outside customers "double the city rates" is continued.

16. Water is sold by a municipality to an industry situated well outside the municipal boundaries. The industry consumed 28 per cent of the total water pumped and paid 14 per cent of the total revenue. The metered commercial customers inside the municipality consumed 9 per cent of the water pumped and paid 11 per cent of the revenue. The metered domestic customers used 10 per cent of the water pumped and paid 33 per cent of the revenue.

17. A city in Ontario sells water to several outside areas at 15¢, but one village pays 5¢ per 1,000 gal. The village is situated on Lake Ontario at the outlet of a river which carries untreated sewage from this and other municipalities, thus practically prohibiting it from taking a supply from Lake Ontario. Hence the low rate for supplying water, compared with the rate in the other outside areas.

18. In 1944 it cost the city of Kingston 6.02¢ per 1,000 gal. to produce water. Water is sold to the Aluminum Company, which is situated outside the city, for 7¢ and to the Canadian National Railways for 6.84¢ per 1,000 gal.

Kingston, in 1943, placed meters on 53 flat rate services in order to secure a comparison between what was being paid on the assessment basis and what would have been paid on a meter basis. Summarizing the situation it was found that:

a. One flat rate service was paying the same amount as shown by the meter.

b. Four flat rate services were paying $125.47 more than the meter charges. This was mostly accounted for by one service which paid $112.40 more than the meter indicated.

c. Forty-eight flat rate services were paying $874.94 although the meter called for payment of $2,743.20. This was an undercharge of $1,868.26, or 313 per cent.

In Kingston there are 286 customers assessed at $500 who pay $3.00 per annum for water, or less than 1 cent per day. An average of probably four persons live in each house. Under the meter rates, a dwelling house paying $3.00 per annum would be using 17 gpd. per service. Again there are 5,874 services on a flat rate assessment paying an average of $7.04 per service per annum. Assuming five persons to each house and computing the volume of water on the meter rate basis that $7.04 would purchase, each person would use 8 gpd., an absurd figure since practically all such houses are connected to the local sewer in the street.

19. The township of North York recently decided to amalgamate its nine water areas into one. All mains in the nine areas were constructed under the terms of the Local Improvement Act. The revenues, expenditures and water used in each of the nine areas were not kept separate. Although it was felt that one of the areas had initially borne the heavy end of the capital expenditures made in establishing the system, there was no proof. Ultimately, it was decided to consolidate the entire nine areas on an equal basis.

20. A customer asked a water works engineer for a supply of water to a large number of temporary buildings being used as a war measure. The customer offered to pay a flat rate of $12 per month or $144 yearly for the water supplied. The engineer saw the mains being constructed in the development and, recognizing the leakage must be very heavy, insisted on the supply being metered. In 1945 this customer paid $13,866.99, which represents 10 per cent of the water works revenue and 7 per cent of the total water pumped.

Conclusions

The author believes that the setting up of a sound rate structure is almost impossible. From an actuarial viewpoint, there should be no particular difficulty if the facts are all available. There are, however, many political difficulties in the way, particularly where industries are concerned, because efforts are invariably made to get an industry established in the district by offering water frequently at less than cost, as well as by giving a fixed assessment. There is considerable objection to increasing the rates to what the water actually costs to the small consumers, and in many cases free water is given for institutional and municipal buildings. When it is considered that the cost of fire protection often amounts to 25 per cent of the total operating and debt expenditures for water works purposes, the amount generally received out of the tax rate for fire protection appears wholly inadequate.

Although the possibility of getting a definite rate structure adopted is extremely small, there is considerable room for improving the existing set-up. There is no doubt whatever that selling water by meter is the fairest way for all concerned, provided the rates are equitable to all customers and make full provision for meeting the annual expenditures, including maintenance, operation, depreciation and debt charges. So much trouble has arisen from the installation of private hydrants and the illegal use of water therefrom that all such private hydrants should be metered. In most cases the existing sliding scales should be revised, and in the author's opinion there is little justification for more than three or at the most four, rates to be included

in the sliding scale. Certainly, in all municipalities, every customer other than the ordinary residence should be metered. The cost of supplying the meter should be paid by the property owner outright, or, if this is considered a hardship, a rental basis should be adopted.

A water works system cannot operate on a sound business basis if it supplies water free. When free water or water at a reduced rate is supplied to certain institutions, the water works system should be given full credit and the reduction recorded in the financial set-up as a contribution from the water works system to such institutions. The amount consumed in street watering, flushing of sewers, public parks and municipal buildings amounts to a considerable quantity each year and should yield revenue.

Canada has no grading schedule similar to the one used by most of the fire insurance rating organizations in the United States. Fire protection reports are issued from time to time by the Canadian Underwriters' Association, following a physical examination of the water works system, fire department, fire alarm system, police protection, building by-laws and the fire record over a period of years. Canadian municipalities are under a distinct handicap, however, in lacking a satisfactory yard-stick to measure their relative standing. The underwriters' reports give detailed information on system deficiencies, but the difficulty of the operating board is to ascertain definitely the comparative value to be placed on each.

There is great need throughout Canada for a better understanding by the water works authorities of the relationship between their industry and the fire insurance business. The average water works engineer has little or no knowledge of how the fire insurance rate has been established. A knowledge of the requirements set up by the underwriters would reveal the weaknesses of each system and would thereby be an incentive for the reduction of grading deficiencies to a minimum. With such a grading schedule, the water works engineer would be in a much better position to approach his superiors with plans for improving the system. The deficiency schedule might, for instance, clearly indicate that the sum of $50,000 could more effectively be spent on the fire department than on the water works system.

It is further suggested that closer co-operation should exist between the underwriters and the water works engineers. In the present procedure, tests are made, the system is sized up and a report is issued to the municipality indicating the defects, and there the matter invariably ends. The water works engineer should be able to summon the underwriters before his board to back up the recommendations he may make on the basis of their report of deficiencies.

Some business-like means of determining what fire protection actually costs in a municipality is a pressing need in Canada. Water works systems should be run on sound business lines, and the customers should benefit directly from their efficiency. Selling water to certain industries at less than cost can only be done at the expense of the other customers, and so cannot be defended. Charges, whether for the water actually used in homes and industries, or for fire protection, should be adequate and fair. Only the service rendered and the benefits offered should determine the rates.

Control of Taste and Odor From Industrial Waste

By C. D. Adams

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Presented on Apr. 3, 1946, at the Indiana Section Meeting, West Layafette, Ind.

DURING the war, problems were created by the TNT, synthetic rubber and powder plant wastes at New Albany, Ind., which the Ohio River was forced to carry. The difficulties became evident in 1943, were acute during the summer of 1944, and continued so until the first of March 1945.

Experimental work carried on during 1943 indicated that free residual chlorination could be used for removing the TNT and synthetic rubber plant wastes, but that the amount of chlorine required would be relatively high (see Fig. 1). Accordingly, the capacities of the existing chlorinators were increased to their maximum, and additional equipment was ordered.

During September 1944, the concentrations of waste in the river were such that existing equipment failed to produce a constant supply of satisfactory water. At times the water in the distribution system contained obnoxious tastes and odors and was highly colored.

New Albany Plant

The plant, which was constructed in 1916, utilizes two primary settling basins, one of 5.5-mil.gal. capacity, or two days' retention, and one of 16.0-mil.gal. capacity, or approximately six days' retention. Mixing is of the over-and-under baffle type, and settling after chemical treatment is obtained in a 1.2-mil.gal. basin equipped with around-the-end baffles. The filters consist of four 1.0-mgd. units. Storage is in a 1.2-mil.gal. clear well. The water is delivered by gravity under an average pressure of around 80 lb.

Control Methods

TNT Wastes

There were three phases to the problem. The first and probably the most important from the customers' viewpoint was that caused by the TNT wastes. Ruchhoft (1) has since pointed out that the TNT wastes (alpha TNT, 2,4,6-trinitrotoluene) can be present in water in either the colorless TNT, or the colored TNT complex, form. Wastes came to the New Albany plant in the colorless condition, but became colored in the distribution system. When water bearing them was treated with chlorine, tastes and odors became progressively worse as the combined residual chlorine portion of the chlorine residual curve was traversed. When the point of free available chlorine residual was reached the tastes and odors disappeared.

The new chlorination equipment was placed in service on Dec. 10, 1944, with all the chlorine being applied ahead of the other chemicals. This practice was established to obtain the maximum of retention, settling and mechanical removal of any colloidal particles formed. Previously, it had been at times neces-

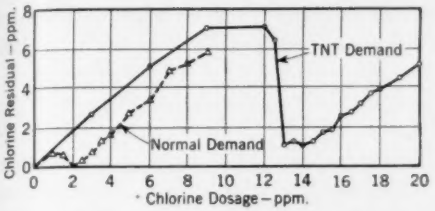

FIG. 1. Effect of TNT Wastes on Free Residual Chlorine Demand

sary to drop the chlorine dosage to the minimum that would still maintain water of safe bacteriological quality, in order to diminish the effects of the wastes.

The constant free available residual chlorine afforded by the new equipment produced excellent results. The plant effluent possessed neither taste, odor nor color. Activated carbon was being used at this time.

A rise occurred in the river during the latter part of December, and the carbon was discontinued. When the river reached the low stage again and brought a recurrence of the problem, it became evident that further use of activated carbon was unnecessary.

In standardizing the control of the process, frequent chlorination curve determinations were required. These disclosed the fact that the change from the colorless TNT wastes to the colored complex was dependent upon the amount of free available chlorine present. From Fig. 2 it will be noted that little change occurred until free chlorine was present. From then until a maximum color was reached, the rate of change was almost a direct function of the amount of chlorine added. After that the change back to the colorless form was likewise in proportion to the chlorine added. These facts were helpful in specifying the chlorine dosage.

It was possible to maintain a residual of about 1.3 ppm. free available chlorine in the plant effluent without producing either chlorine taste or odor. As the residual increased above this value both were noticeable. Thus it seemed likely that not all of the TNT wastes could be removed by the chlorine treatment without resorting to de-chlorination. A dosage was specified which the curve indicated would remove 60 per cent of the TNT wastes. They were not present in the finished water.

The rate of change of the TNT waste from the colorless to the colored form was also dependent upon retention time after chlorination. This made excessive chlorination followed by dechlorination unnecessary. The effect is shown in Fig. 3.

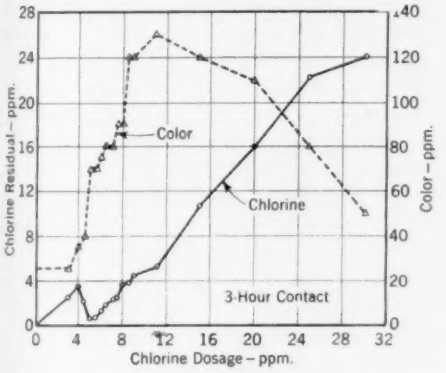

FIG. 2. Effect of Chlorine on TNT Wastes

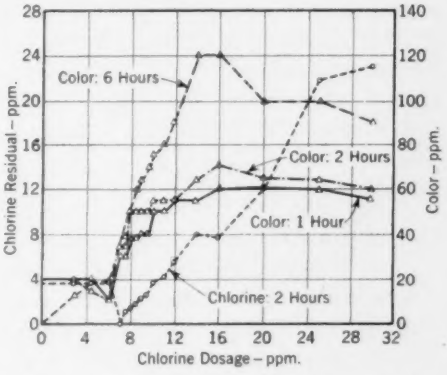

FIG. 3. Effect of Time After Chlorination

Several other facts were also noted during the study:

The rate of change of the TNT wastes from the colorless to the colored form depended, again, upon the pH of the water. This effect is shown in Fig. 4. Since soda ash was being used at the time, it may have played its part in the removal process; however, Figs. 2 and 3 represent water without soda ash treatment.

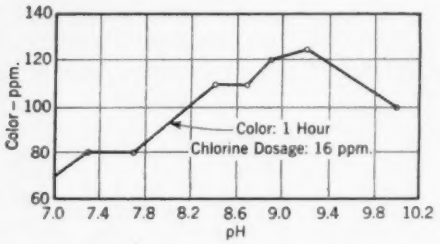

FIG. 4. Effect of pH on TNT Wastes in Free Residual Chlorinated Water

Colored TNT wastes became colorless upon removal of the chlorine by chemical means. Removal of the chlorine by boiling did not produce the change.

When water containing TNT wastes was treated with small amounts of chlorine (combined chlorine residual), contact with iron slowly changed it to the colored form. This fact was very troublesome during the fall of 1944.

After the TNT wastes were changed to the colored form by chlorination, they coagulated and settled out in red clumps within 48 hours. The clarification obtained by this action was excellent.

Synthetic Rubber Wastes

The process involved in the removal of the synthetic rubber plants wastes was not so clearly defined. The compounds, which were believed to include benzol, ethyl benzine, ethyl alcohol and aldehydes, as well as butadiene and styrene, were not expected to react favorably with chlorine. The odors and tastes produced by them were difficult to define, having somewhat of a kerosene base, but they were easily recognizable. The compounds were invisible throughout the entire process, but their removal was complete. Not a single complaint concerning them was received after December 15.

Acid Wastes

The third phase of the problem was produced by the corrosiveness of the water. The powder plants partially neutralized their wastes by treatment with limestone. The raw water, then, possessed low alkalinity and relatively high concentrations of chlorides and sulfates. Lime treatment, even above saturation pH, was ineffective. E. B. Evans, in a private communication to the author, outlines the procedure followed at Cincinnati to eliminate "red water" complaints as follows:

> The procedure of using soda ash under the conditions met with during our "red water" period is not a new one. Our theory of the matter was that the low total alkalinity and the presence of magnesium chloride to the extent of 10–15 ppm. in the finished water caused the trouble. The addition of soda ash in a quantity such that the total alkalinity was raised left more sulfate ion to be accounted for in the hypothetical combination of the ions, and therefore the magnesium combined as sulfate instead of as chloride in the water.
>
> Also at the same time . . . we had an appreciable amount of color in the water which caused the consumers to say that they had "red water" in their taps. This color, which was not noticeable in a tumbler, became very apparent in bathtubs and wash stands when the water was drawn to a depth of about 6 in. The color was found to be due to a salt of

TNT, and it also caused some corrosive action in the distribution system.

Increased lime treatment only aggravated the condition by decreasing the total alkalinity, which caused the water to become more corrosive in nature.

This same procedure was employed to eliminate the "red water" problems at the New Albany plant.

Control Aftereffects

In addition to the above and the already published benefits of free residual chlorination, the following results were noted during 1945:

1. The taste and odor compounds normal to the Ohio River were eliminated.
2. The growth of algae in the basin used for settling after chemical treatment was controlled.
3. Flocculation was aided; however, this aid was tricky, and if not watched closely it peptized the floc and thereby raised the cost of alum treatment.
4. The lactose-fermenting organisms were practically eliminated from the New Albany water.
5. The treatment produced a savings in chemical costs, especially during the summer months when considerable amounts of copper sulfate and activated carbon were normally used.

Control of Algae

The control of the algal growths in the settling basin was unexpected. Previously, "blackout" with activated carbon was the only remedy. The treatment was usually started in May and ended in November. In 1945 the use of the carbon was not started until August 4 and was used only until October 14. Had the settling basin been of modern design, with even flow throughout, it is quite probable that even this use of the carbon would have been unnecessary. It should be pointed out, however, that in the opinion of others such control of algae is possible only in water of low concentrations of bicarbonate alkalinity. The yearly average of this alkalinty was 58 ppm. in 1945, but through August and September it averaged 80 ppm.

Control of algae by chlorination requires constant vigilance, as the chlorine dosage must compensate for the changing chlorine dissipation during the day by the changing intensity of sunlight. There were times during 1945 when the amount of chlorine lost was greater than expected. As this occurred, additional chlorine was added in order to maintain a free chlorine residual of from 1.0 to 1.5 ppm. in the plant effluent.

Control of Bacteria

Table 1 shows the effect of free residual chlorination upon the control of lactose-fermenting bacteria. It will be noted that a total of 1,124 samples were planted from the plant effluent, the clear well effluent and the distribution system, and that only fourteen samples showed the presence of the lactose-fermenting organisms. Three of these were from the plant effluent and two were from the clear well effluent. Of the remaining nine, seven were collected from an area where concrete lining of mains was in progress. In addition, 1,188 plantings of 100-ml. portions of the plant effluent were made. Only nine, or 0.77 per cent, showed evidence of the gas-producing organisms. Further, all but one of the samples showing the presence of the gas-producing organisms were handled by inexperienced operators who were being trained in bacteriological technic. Thus free residual chlorination has practically eliminated this bacteria.

TABLE 1

Control of Lactose-Fermenting Bacteria by Free Residual Chlorination

Month	Plant Effluent		Clear Well Effluent		Distribution System	
	Planted	Showing Gas	Planted	Showing Gas	Planted	Showing Gas
December 1944	31	0	31	0	25	0
January 1945	31	0	31	0	25	0
February	28	0	28	0	25	0
March	31	0	31	0	26	0
April	30	0	30	0	25	0
May	31	0	31	1	25	1
June	30	0	30	0	26	0
July	31	0	31	0	27	0
August	31	0	31	0	28	1
September	30	1	30	0	27	0
October	38	0	31	0	26	2
November	34	2	30	0	18	5
December	31	0	31	1	18	0
Total	407	3	396	2	321	9

Distribution of Residual Chlorine

Concern was felt about how the free residual chlorine would carry through the distribution system, and whether or not taste or odor from it would develop. A study pertaining to this particular phase of the treatment was carried on from March through November 1945. Twelve sampling points were established in such a manner as to obtain typical samples from the entire distribution system. Samples were collected in clean, sterile bottles and were transported as rapidly as possible to the laboratory. Most of the time, the same individual made determinations of the odor, taste and the immediate and 5-minute residual chlorine values. Field tests showed that very little chlorine would be lost during the transit of the samples. Monthly average results of the analysis of two sets of samples per week brought out several facts:

1. Practically no chlorine taste developed.

2. Slight chlorinous odors were common, with less appearing during August and September.

3. The chlorine did not distribute evenly throughout the distribution system.

4. Very little chlorine reached the extremities of long dead-end mains.

5. The chlorinous odor was not consistent with relation to the chlorine residual.

Tuberculation

The New Albany water distribution system, like other Ohio River supplies, is affected by tuberculation. This is the result of the reproduction of sulfate-reducing bacteria. In each tubercle there is a slight passageway which probably serves two purposes: the venting of excess gases and the replenishing of the supply of water to the organisms. Evidently the amount of chlorine reaching the organisms through this process is so infinitesimal that it can have no effect upon them; therefore their re-

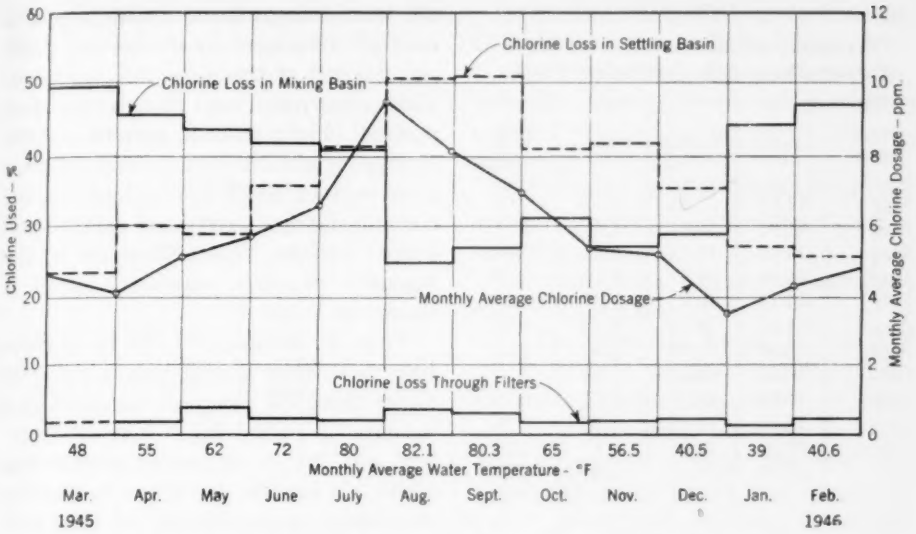

FIG. 5. Effect of Seasonal Temperature Variations Upon Chlorine Demand

production continues. On the other hand, there probably is enough hydrogen sulfide or other gas liberated to remove the chlorine normally carried in the water by the time that water reaches the extremities of the distribution system.

Results

At the present time it appears unlikely that the chlorinous odors can be removed from the New Albany water supply. Since the water in the distribution system is under approximately 80-lb. pressure, the opening of a tap, by reducing the pressure to the atmospheric level, produces a boiling effect which releases the chlorinous odor It is possible that differences in static pressures within the distribution system tend to produce the odors. It was noted that samples from Station 7 always contained chlorinous odors; this location is at an elevation where pressure is approximately 15 psi. less than the average in the downtown section. Further study, however, is required before any definite statement can be made about this assumption.

Compilation of the chlorination control data brought out the fact that more chlorine is consumed in the mixing process during the winter than during the warmer months. When this is considered in terms of percentage of the chlorine lost in each step of the purification process, the results shown in Table 2 are obtained. The same data, with the exception of the clear well storage, are presented graphically in Fig. 5.

Evidently the increased amount of suspended material in the raw water during the winter is responsible for the higher immediate chlorine demand during that period.

Costs

Prior to the war era, two 40-lb. type MSVM Wallace and Tiernan chlorinators afforded ample capacity for free residual chlorination. The chlorine demand of the Ohio River water became progressively higher as the

TABLE 2

Percentage of Chlorine Consumed in the Various Stages of the Purification Process

1945 Month	Mixing	Settling	Filtering	Clear Well Storage
Mar.	49.63	22.85	——	2.95
Apr.	45.94	30.11	1.55	1.73
May	43.92	29.16	3.63	2.08
June	41.41	35.61	2.30	2.45
July	40.33	40.96	2.21	4.00
Aug.	24.32	50.24	3.55	6.97
Sept.	26.40	51.08	2.60	3.03
Oct.	30.81	40.59	1.84	5.72
Nov.	26.64	41.51	2.12	6.76
Dec.	28.40	35.00	2.20	2.56
Jan.	44.20	26.95	1.17	1.64
Feb.	47.20	25.36	2.24	1.28

tempo of the war effort increased, however, and the items required to satisfy the increased demand were:

1. The purchase of one 400-lb.-per-day Wallace and Tiernan chlorinator.
2. The purchase of one 7,000-lb. capacity platform scale.
3. Building alterations, which included doorway, track and trolley, hoist and chlorinator room.
4. The purchase of an electrically operated crane for unloading ton containers of chlorine from railroad cars.
5. The construction of a storage shed for carload lots of ton containers of chlorine.
6. Increased amounts of chlorine.

When the size of the supply is considered, these factors represent a considerable investment. Offsetting that, however, is the decreased unit cost of chlorine when purchased in ton containers, as compared to the cost when it is purchased in 150-lb. cylinders. This fact should be kept in mind when considering the data in Table 3. From this table it can be seen that even though the war plants were shut down in August 1945, or shortly thereafter, the wastes from them caused a yearly over-all treatment cost rise of $2.88 per mil.gal. at the New Albany plant. This occurred even though the free residual chlorination treatment and the change in chlorine containers effected a savings of $1.79 per mil.gal. in the cost of chlorine, activated carbon and copper sulfate. The difference in the amounts of these chemicals used is shown in Table 4.

Thus, by the use of 7,784 lb. of chlorine more than would have been used under the 1944 practices, an estimated savings of 14,612 lb. of activated carbon and 963 lb. of copper sulfate was made. When the difference in the cost of chlorine is considered, the total estimated savings in cost of treatment is $1,742.21. Therefore the investment in the new equipment necessary for maintaining free residual chlorination was a good one. The saving in the use of activated carbon was accomplished, for the most part, by the control of the algae in the settling basin. Copper sulfate is primarily used in batch dosages for the control of the algae in the primary settling basins, where the free residual chlorine treat-

TABLE 3

Summary of Annual Average Treatment Costs

	1944	*1945*	*Difference*
Mil. Gal. treated	863	973.3	+110.3
Turbidity	54	70	+ 16
Alum	$1.92	$2.85	+ $0.93
Lime	0.71	0.49	−0.22
Soda Ash	0.79*	4.75	+3.96
Chlorine	2.22	1.41	−0.81
Carbon	1.10	0.17	−0.93
Copper Sulfate	0.13	0.08	−0.05
TOTAL	$6.87	$9.75	+$2.88

* Soda ash treatment started in November 1944

ment permitted heavier growths of the algae in 1945 than had previously been allowed. The assumption behind this procedure, which has been employed in other water purification plants, is that,

TABLE 4

Average Annual Chemical Dosages — lb. per mil. gal.

	1944	*1945*	*Difference*
Activated Carbon	17.6	3.05	−14.55
Chlorine	40.7	48.7	+8.0
Copper Sulfate	2.16	1.17	−0.99
Water treated, *mil. gal.*	863	973.3	+110.3

by permitting heavier algal growths in the settling basin, less organic matter will be present in the water taken for treatment. No detrimental effects of the increased algal growths were noted in the finished water. The savings in these chemicals was, as stated above, erased by the increase of cost occasioned by slightly higher turbidity of the pre-settled water and by the use of soda ash for corrosion control.

Conclusions

From the foregoing experiences, the following conclusions were drawn regarding the use of free residual chlorination:

1. It successfully removed the tastes and odors caused by war plant wastes.
2. It was a good means for the control of algal growths in the settling basin used after chemical treatment during the early summer and late fall months of the year.
3. It was instrumental in bringing about a savings in the amounts of activated carbon and copper sulfate normally used.
4. It removed TNT wastes from the Ohio River water at New Albany, Ind., by changing it from the colorless to the colloidal colored form which subsequently coagulated, settled or was filtered from the water.
5. Its role in the removal of the synthetic rubber plant wastes has not been determined.
6. It produced a water of excellent bacteriological quality.
7. The necessary usage of soda ash for corrosion control materially increased the cost of chemical treatment.
8. The untreated domestic and industrial wastes during the war era which the Ohio River was forced to accept caused an overload upon the stream which resulted in non-palatable water being delivered at times to Ohio Valley consumers, and an increase in treatment costs at the plants using the stream as a source of supply.

Finally, it should be mentioned that it is not the intent of the author to imply that by the use of free residual chlorination all other methods of removing tastes and odors can be dispensed with. Each has its own particular advantages, and each should be used when needed. The purpose, rather, has been to describe how a condition in the Ohio River, which, because of advances in wastes treatment, probably will not occur again, was successfully handled at the New Albany water purification plant. Even though the results of free residual chlorination have been excellent, ample supplies of activated carbon are being kept on hand for any emergencies that might arise in the future.

Reference

1. Ruchhoft, C. C., LeBosquet, M., Jr. & Meckler, Wm. G. TNT Wastes From Shell-Loading Plants. Ind. Eng. Chem., **37**: 937 (1945).

DISCUSSION—*N. S. Chamberlin*

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Many water treatment plants had taste and odor troubles, particularly during the war years, because of industrial wastes. The experiences at New Albany were quite similar to those at other plants on the Kanawha and Ohio rivers.

Usually, more than one waste was present to complicate the picture, and usually one or two of these were present in sufficient quantity to insure their identification. At New Albany, the characteristic taste and the yellow color of TNT in water resulted in the identification of this waste, and the odor of butadiene and styrene made possible the identification of synthetic rubber plant wastes.

But the identity of any specific waste means but little when several are present in the water to be treated, since the proper treatment for one waste is seldom the proper treatment for another. The usual mixture that one had to contend with in wastes made it more difficult to treat the water at all times in a satisfactory manner. A slightly different problem was created at each individual plant, New Albany among the rest. Each plant had to solve its own problem by diligent experimentation and perseverance. It is amazing indeed that the plants on the Kanawha and Ohio rivers, New Albany included, have been able to deliver to the consumer a more or less palatable water.

Experimentation and final plant practice made use of one or more of the following: aeration, activated carbon, chlorine in amounts sufficient to obtain free available chlorine residuals and chlorine dioxide. Many plants, like that at New Albany, made use of free available chlorine residuals to aid in controlling the tastes and odors resulting from the presence of industrial wastes. It is significant that chlorine in this form is effective in treating not one but a variety of wastes, even when present in a single raw water supply. Most industrial wastes can be oxidized to a degree by free available chlorine. That this occurred at New Albany was evidenced by the fact that the chlorine demand increased whenever TNT was present in the water entering the plant.

Chlorination can control tastes and odors resulting from the contamination of water supplies with industrial wastes in various ways; the process is not necessarily oxidation. Knowledge of the industrial wastes receiving chlorine treatment at the New Albany and other plants evidences that free available chlorine, as obtained by free residual chlorination, reacts in one of the three following ways, depending upon the specific waste:

1. Oxidation of the waste products having taste and odor to soluble tasteless and odorless products. Often such oxidation products are simpler compounds than the unoxidized compounds. Where simpler compounds are formed, the term "burning-up" has often been applied.

2. Oxidation of the waste products having tastes and odors to products insoluble in water. Products eliminated in such a manner are usually not simple compounds but insoluble chlorine substitution derivatives of the original taste- and odor-producing compound.

3. Volatilization of the taste- and

odor-producing substance, using as a vehicle the volatility of nitrogen trichloride, NCl_3, one of the end products obtained when chlorine is added in excess to water containing ammonia.

A good example of the destruction of taste and odor compounds by oxidation is found in the essential oils secreted by algae. Upon chlorination, the free available chlorine residuals oxidize these unsaturated oils to saturated compounds of an entirely different nature —compounds that are usually tasteless and odorless. An example of the destruction of compounds that are toxic, although not necessarily having a taste and odor, is that of cyanides in industrial wastes. Upon the application of high doses of chlorine, the cyanides are literally "burned up"; they are completely destroyed, producing a series of less complex compounds that are harmless, odorless and tasteless. Cyanogen chloride is formed, and this in turn hydrolyzes into carbon dioxide, ammonia and hydrochloric acid. Probably the greatest diversity of organic matter oxidized by chlorine, often to simpler compounds, is that reported by Borg at the synthetic rubber plant at Institute, W.Va. (1). The synthetic rubber latex showed a tendency to coagulate everywhere in the plant except where it should have, and organic matter in the process water was found to be the main reason. By destroying this material with free available chlorine, the process water was found to be satisfactory for manufacturing purposes.

The oxidation of phenols is a good example of the destruction of taste and odor compounds by oxidation with chlorine to insoluble chlorine substitution derivatives. Free available chlorine reacts with the phenol to form the chlorine substituted derivative, pentachlorphenol. This compound is practically insoluble in water, particularly so if the pH of the water is 6.0 or less. Todd at Wheeling has probably removed phenols from the water in this manner on numerous occasions. TNT in the water at New Albany is another example. The alpha-TNT received at the plant is colorless, but the application of chlorine in an amount sufficient to produce free available chlorine residuals apparently produced in the settling basin a golden-colored oxidation product of the TNT, a product which forms a red precipitate. This product in all probability is different from the colored form of TNT found prior to the treatment in the distribution system and should not be confused with the colored "sellite" product in the waste from a TNT manufacturing plant. The oxidized product formed at New Albany, so it appears, had its greatest stability in an excess of chlorine and at elevated pH values.

These reactions of TNT with chlorine are apparently analogous in some respects to pulp and paper mill waste reactions with chlorine. At the Bangor, Me., water treatment plant, free available chlorine residuals at low pH's —around 5.0—oxidize the cellulose and lignin compounds to a red colored product that precipitates in the settling basin or is deposited on top of the rapid sand filter. Unlike the TNT product, this redissolves when the pH increases to 7.0 or more. At Bangor, therefore, pH adjustments are made in the filtered water to prevent the chlorinated derivatives from redissolving.

Volatilization of taste and odor producing substances can occur, as mentioned, using nitrogen trichloride as a vehicle of volatilization. This is the reason why free residual chlorination at New Albany was successful in coping with the synthetic rubber wastes.

When water containing ammonia, such as that at New Albany, is treated with an excess of chlorine, nitrogen trichloride is formed and immediately starts to volatilize from the water, as evidenced by the typical chlorinous odor present at the plant. When butadiene and styrene are present, chlorine probably produces chlorinated derivatives, but these differ little in odor and other physical characteristics from the unchlorinated compounds. Both have a tendency to volatilize, and are carried off along with the nitrogen trichloride.

That this actually occurs has been proven by the presence of butadiene and styrene in water containing little ammonia. After chlorination, the odor of butadiene and styrene was still quite pronounced. But when a small amount of ammonia was added to the same water before free residual chlorination, the butadiene and styrene left the water along with the nitrogen trichloride.

Reference

1. Borg, Leonard. Water Treatment at the Institute, W.Va., Synthetic Rubber Plant. Jour. A.W.W.A., **37**: 209 (1945).

Stream Pollution in Southwestern Pennsylvania

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Presented on Sept. 14, 1945, at the Western Pennsylvania Section Meeting, Pittsburgh, Pa.

THE scope of this paper will be limited to the southwestern Pennsylvania territory, which includes the counties of Allegheny, Fayette, Greene, Indiana, Somerset, Washington and Westmoreland. This area is drained by the Ohio River watershed, with the exception of a very small section of Indiana County which is on the watershed of the Susquehanna River, and a small portion of Somerset County which is on the Potomac River watershed. The main tributaries to the Ohio River draining the watershed are the Lower Allegheny River and its main tributary, the Kiskiminetas River, and the Monongahela River and its main tributary, the Youghiogheny River.

The territory is generally rugged in topography, with a large number of small streams tributary to the main rivers draining the terrain.

The area as a whole is fairly densely populated. This is especially true in the river valleys where a large part of the population is located in communities stretching along the courses of the streams.

The area is predominantly industrial in character and has been built up around the steel and coal industries. The chief mineral resource of the district is bituminous coal and much of the territory which is drained by the Ohio River watershed is underlain with rich deposits of this coal. There are at present active coal mining operations on a major scale in each of the counties in this area.

The 1940 census population of the district was aproximately 2,336,000, distributed over an area of about 5,900 square miles, with densities varying from a maximum of 1,933 per square mile in Allegheny County to a minimum of 77 per square mile in Greene County, with an average population density of approximately 400 per square mile. This population is also distributed throughout 407 separate municipal subdivisions, including cities, boroughs and townships of the first and second classes.

Types of Pollution

The types of pollution presently encountered in this area can be naturally divided into three general classifications: (1) municipal sewage, (2) industrial waste produced by manufacturing establishments in processing and (3) drainage from bituminous coal mining.

Municipal sewage contains the excrementitious and other human waste discharges in the spent water supply and may contain various types of industrial wastes discharged to sewage systems. These wastes are generally organic.

Industrial wastes from manufacturing establishments using water supply

in processing material may contain in the spent water supply wastes of an organic or inorganic nature. Certain types of industries produce organic waste waters similar in pollutional character to municipal sewage except for the bacterial content and the varying pollutional strength. Such waste waters are encountered from industries such as breweries, distilleries, paper mills, creameries, canneries, textile establishments and others.

Some industrial wastes are, however, mineral in nature and these types of wastes are generally encountered in metallurgical mills. They are generally acid in character and are produced from pickling, rinsing and plating processes.

Bituminous coal mine drainage is also of a mineral nature and is generally characterized by its acid content, including free and mineral acids such as sulfuric acid and iron and aluminum sulfates, the chief pollutional constituent being the sulfate content, which is present in all forms.

These various wastes are of a pollutional nature because of their malign effects on the waters flowing through the water courses as surface supplies, especially since such wastes are generally discharged to surface streams.

Sewage contains, in addition to appreciable amounts of decomposable organic matter, a very high bacteria load, including organisms which are capable of producing disease. When discharged to waters in sufficient quantities to overcome the natural assimilating powers of the streams, they render such waters unfit for recreation; destroy fish life; deplete the natural oxygen content of surface water supplies, sometimes to the point of exhaustion, with the resultant creation of odor nuisances; render stream waters turbid; deposit sludge and floating scum on the waters; and render streams unsafe for use as domestic water supplies unless given adequate treatment.

Organic industrial wastes, when discharged to streams in excess of the assimilating powers of the waters thereof, have virtually the same effects as sewage, with the exception that the bacterial content and disease-producing organisms are not generally present. Other industrial wastes may contain substances toxic to man, fish and animals and may also create serious taste and odor problems in domestic water supplies.

Wastes from bituminous coal mines and metallurgical mills, when discharged to streams in sufficient quantities, overcome the natural alkalinity of such waters, thereby rendering them acid in character; destroy fish and other aquatic life; render waters corrosive and hard; reduce the oxygen content of the streams; create turbid waters; interfere with recreation; damage structures built in and along the banks of the streams; and render the water unfit for the watering of stock and animals. Such water requires extensive and expensive treatment when used for domestic and industrial purposes.

Scope and Magnitude of Pollution

Sewage

Of the 407 municipalities in the area under consideration, approximately 180 have public systems for the collection and disposal of the sewage. Within these municipalities, there is a total population of approximately 1,800,000 persons, and the estimated sewered population in these municipalities is approximately 1,520,000 persons.

There are 45 sewage treatment works now in existence in 37 of these

municipalities treating the sewage to varying degrees for a population of approximately 120,000 persons. The degree of treatment provided reduces the pollution load by an equivalent untreated sewered population of approximately 55,000, so that the estimated equivalent sewered population as presently discharged in the entire area is approximately 1,465,000.

Industrial Waste

Throughout the watersheds in this area, there are various types of industries producing organic industrial wastes. Some of the organic waste waters are discharged to municipal sewage systems and others are discharged directly to open water courses.

Organic industrial wastes are usually measured in terms of the equivalent sewered population expressed in terms of biochemical oxygen demand, which is generally recognized for raw sewage as being equivalent to 0.167 lb. per capita per day.

The pollutional strength, in terms of sewered population equivalent, is not known for all industrial wastes discharged to sewage systems and streams. Those which are known and for which information is at hand have a pollutional strength in terms of sewered population equivalent of approximately 860,000 persons, after allowance has been made for reduction in the pollution load in treatment works. Therefore, the estimated equivalent sewered population in the southwestern Pennsylvania district, including sewage and industrial wastes as presently discharged, is approximately 2,325,000.

It is interesting to note how this equivalent sewered population pollution load is distributed throughout the various counties on a percentage basis. Allegheny County contributes 78.8 per cent, Fayette 5.8, Greene 0.3, Indiana 0.8, Somerset 4.3, Washington 3.4 and Westmoreland 6.6 per cent.

It is further interesting to note the distribution of the equivalent sewered population pollution load by watersheds. The Monongahela River watershed carries 52.2 per cent, the Allegheny River watershed 33.6 per cent and the Ohio River shed 14.2 per cent.

Acid Wastes

As heretofore stated, acid wastes are discharged mainly from bituminous coal mines. In addition to this source, however, there is an acid stream pollution load from pickle liquors and rinse waters from metallurgical industrial establishments.

The only data available at the present time for estimating the total acid load were secured mainly during the mine sealing program which took place as a Works Progress Administration program sponsored by the state and the federal public health services, and which have been summarized in a report entitled, "Ohio River Pollution Survey, Final Report to the Ohio River Committee, Supplement C—Mine Drainage Studies," which was compiled by the U.S. Public Health Service office of Stream Sanitation, located at Cincinnati, Ohio. This compilation of data gives the present acid load by major drainage basins and states on the Ohio River watershed after the sealing program was effective. The figures used in this report are deduced from that publication as the only figures available.

To this load must be added the load of waste from pickling liquors and the total figures given for acid pollution in this discussion are combined bituminous mine drainage load and industrial acid load.

These combined loads in terms of acid discharged to streams in tons per day include all the acid mine drainage on the Ohio River watershed in Pennsylvania, except the Beaver River, and the industrial wastes are included only for the territory in southwestern Pennsylvania.

These combined loads, in tons per day discharged, are as follows:

Watershed	*Average Discharge tons/day*
Kiskiminetas River	855
Allegheny River (except Kiski.)	185
Youghiogheny River	540
Monongahela River (except the Youghiogheny)	500
Ohio River and minor tributaries (except the Beaver)	110
TOTAL	2,190

Of this total amount, it is estimated that approximately 44 tons per day are acids discharged from metallurgical mills.

The percentage of acid waste pollution discharged to each of the main watersheds is as follows:

Watershed	%
Kiskiminetas River watershed	39.0
Allegheny River (except Kiski.)	8.5
Youghiogheny River	24.6
Monongahela River (except Youghiogheny)	22.8
Ohio and minor tributaries (except Beaver)	5.1
	100.0

It is the author's hope that the presentation of these data will enlighten the water works operators regarding the scope and magnitude of pollution in southwestern Pennsylvania and that it will arouse public interest to a sufficient degree to create a desire for the control of all types of pollution and thereby bring to fruition the policy and program of the Sanitary Water Board of Pennsylvania relative to stream pollution abatement.

Surface Water Supplies of Wisconsin

By O. J. Muegge

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Presented on Nov. 15, 1945, at the Wisconsin Section Meeting, Milwaukee, Wis.

A CASUAL glance at a list of the public water supplies of Wisconsin would give the impression that surface supplies are not of much concern because they are so few in number. A more detailed review, however, would show that, although the surface supplies comprise only 6.75 per cent of the recognized public water supplies, they serve over 52 per cent of the population available to water works systems and over 32 per cent of the state's population. Furthermore, surface sources of supply are used extensively by industries, such as paper and pulp mills, as process water, and large volumes are drawn by power and industrial plants for cooling and condensing purposes. Surface sources are also developed for fire protection by industries, by small communities having no regular water utility and by larger communities as a separate auxiliary system in high value districts. The following discussion, however, will be limited to such supplies as are used to provide water for human consumption.

The relatively small number of public surface water supplies in Wisconsin, as compared to the number in other sections of the country, is due to the general availability and adequacy of ground water resources. In the main the development of surface supplies is limited to the larger municipalities and to communities where ground water supplies are unsatisfactory from the standpoint of quality or quantity. In some instances, at the time of the original development of the water works system, a surface source, rather than a ground water source, was selected because of the lower initial cost of the system.

Heretofore, the trend has been toward a reduction in public surface water supplies. More than 25 such supplies have been abandoned in favor of ground water supplies over a period of about 30 years, during which time less than ten new surface sources were developed. Abandonment of more of the existing surface supplies is in prospect, one before another year has passed. Conversely, however, it is to be expected that some existing ground water sources will be replaced by surface sources because of the unsatisfactory chemical quality of the former, because ground water levels have been lowered or because the present sources are inadequate to meet the increasing consumer demand.

In Wisconsin there are at present 29 surface supplies providing water for human consumption. These supplies serve 26 incorporated municipalities, five town sanitary districts and nine unincorporated communities. The total population (1940 basis) served by such supplies is about 1,011,000.

Of the 29 supply works, nineteen are owned by municipalities, two by public utilities, four by industries, three by Indian agencies and one by a state institution. One of the public utility and

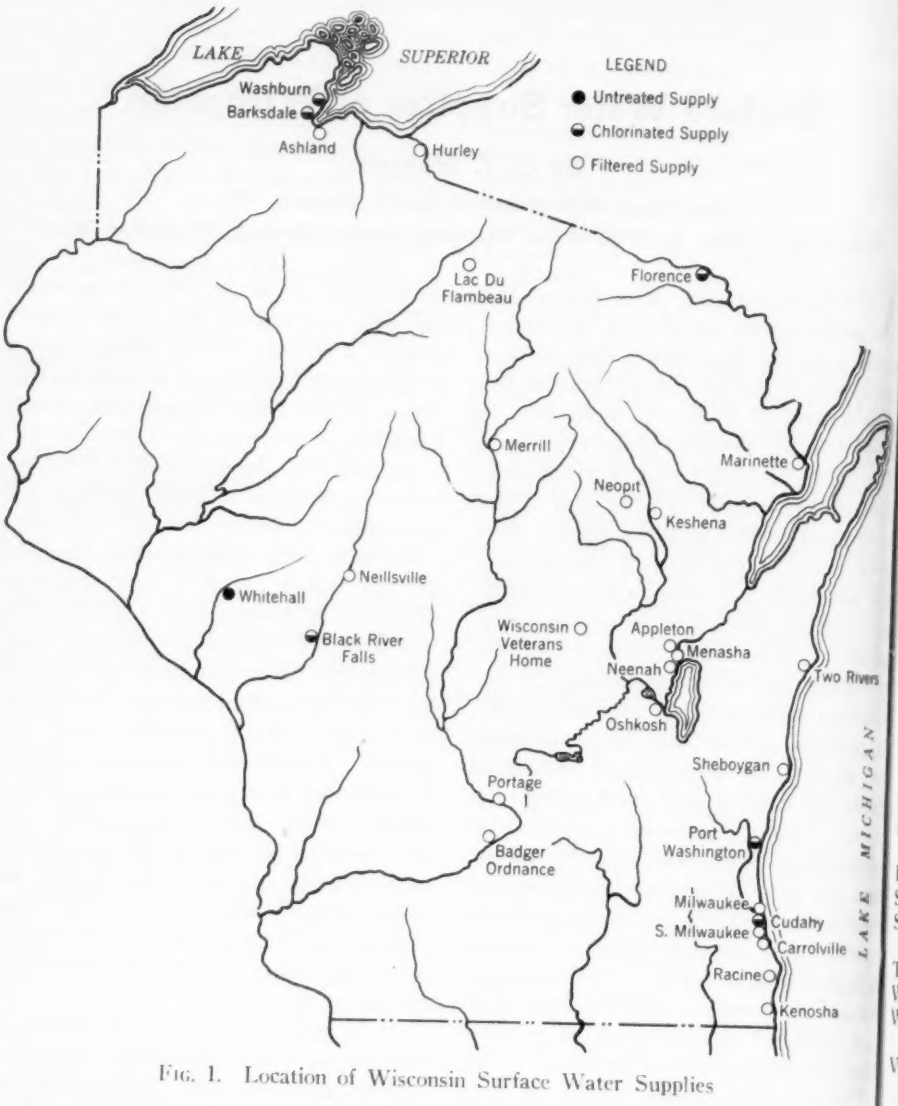

FIG. 1. Location of Wisconsin Surface Water Supplies

one of the industry owned supply works serve municipally owned distribution systems.

Description of Sources of Supply

The location of Wisconsin's 29 supply works is shown in Fig. 1. The source of supply utilized by each of the works, the type of ownership and the population served (1940 basis) are given in Table 1. The tabulation shows that almost one-half of the systems obtain their supply from the Great Lakes, eleven systems drawing upon Lake Michigan and three upon Lake Superior. Six of the supply works depend upon inland lakes, and the remaining nine upon streams. Of the

TABLE 1

Wisconsin's Surface Supplies

Location	*Ownership*	*Source*	*Population*
Appleton	City	Fox R.	28,636
Ashland	City	L. Superior	11,101
Badger Ordnance Works	Industry	Wisconsin R.	3,000†
Barksdale	Industry	L. Superior	150†
Black River Falls	City	Town Creek	2,539
Carrollville	Industry	L. Michigan	200†
Cudahy	Utility*	L. Michigan	10,561
Florence	Town	Fisher L.	800†
Hurley	City	L. Lavina	3,375
Kenosha	City	L. Michigan	48,765
Keshena	Indian Res.	Keshena L.	250†
Lac du Flambeau	Indian Res.	L. Pokegama	200†
Marinette	City	L. Michigan	14,183
Menasha	City	Fox R.	10,481
Merrill	Utility	Prairie R.	8,711
Milwaukee	City	L. Michigan	655,260
Neenah	City	Fox R.	10,645
Neillsville	City	Black R.	2,562
Neopit	Indian Res.	W. Br. Wolf R.	1,200†
Oshkosh	City	L. Winnebago	39,089
Portage	City	Wisconsin R.	7,016
Port Washington	City	L. Michigan	4,046
Racine	City	L. Michigan	67,880
Sheboygan	City	L. Michigan	40,638
South Milwaukee	City	L. Michigan	11,134
Two Rivers	City	L. Michigan	10,302
Washburn	City	L. Superior	2,363
Whitehall	Industry*	Trempealeau R.	1,035
Veterans' Home	Institution	Rainbow L.	700

* Distribution system owned by municipality.

† Estimated population.

latter sources only one, that of Black River Falls, can be considered to be developed for water supply purposes through the installation of a small impounding reservoir. With the exception of the Portage supply, however, the stream intakes are located above dams, six of the dams being installed for power development or industrial use, one for recreational purposes and one to keep the intake covered during low flow periods.

None of the drainage areas of either the lake or stream sources is owned or regulated by any of the water works. The sources of supply at Black River Falls, Florence, Hurley, Keshena, Lac du Flambeau, Neopit and Wisconsin Veterans' Home receive no known direct sewage pollution. Invariably, the communities using the Great Lakes as a source of supply dispose of their sewage and industrial wastes into the lake, sewage treatment being provided except at Port Washington, Ashland, Barksdale and Washburn. In all instances, communities drawing upon streams as sources of supply discharge their sewage below the water works intake. Except for supplies previously noted, however, upstream communities and industries contribute pollution to such sources. From the bacteriological standpoint the effects of such pollution are most pronounced at Appleton, where the intake is located but a few miles below the twin cities of Neenah and Menasha. The sewage from these cities receives primary treatment in a jointly owned plant.

Purification Facilities

Only one of the surface water supplies, namely that at Whitehall, has no treatment facilities other than that of sedimentation for reduction in turbidity. This supply is not commonly used for drinking purposes as most residences are equipped with individual well systems. A ground water supply is presently being developed by the city to replace the surface source.

Six of the supplies—Barksdale,

Black River Falls, Cudahy, Florence, Port Washington and Washburn—utilize only chlorine disinfection. The installation of filtration plants at Cudahy and Port Washington is in prospect at an early date. Similar installations or the development of ground water sources have been recommended for the other systems.

Treatment facilities at the other 22 surface supply works include filter plants, the type and capacity of which are shown in Table 2.

TABLE 2

Filtration Plants

Location	*Type of Plant*	*Capacity 1,000 gal.*	*Remarks*
Appleton	Gravity	8,000	Softening also
Ashland	Slow sand	1,600	
Badger Ordnance Works	Gravity	40,000	
Carrollville	Pressure	2,780	
Hurley	Gravity	700	
Kenosha	Gravity	14,000	
Keshena	Pressure	40	Carbon filters also
Lac du Flambeau	Pressure	30	Carbon filters also
Marinette	Gravity	3,000	New plant proposed
Menasha	Gravity	4,000	
Merrill	Gravity	1,500	
Milwaukee	Gravity	200,000	
Neenah	Gravity	2,000	Softening and carbon filters
Neillsville	Pressure	310	
Neopit	Gravity	250	
Oshkosh	Gravity	6,000	Carbon filters also
Portage	Gravity	2,000	
Racine	Gravity	20,000	
Sheboygan	Gravity	18,000	
South Milwaukee	Gravity	2,500	Addition planned
Two Rivers	Gravity	2,000	
Veterans' Home	Gravity	290	

The filtration plants listed in the table comprise one slow sand filter plant, four pressure sand filter plants and seventeen gravity or mechanical sand filter plants. The combined capacity of these purification plants is 329 mgd.

Granular carbon filters are used for supplementary treatment at four plants. They are used at Keshena and Lac du Flambeau for de-chlorination and at Neenah and Oshkosh for odor control. The efficacy of the carbon filters at Neenah has been materially reduced because of incrustation.

Water softening facilities were incorporated as part of the original filtration plant installations at Neenah and the Wisconsin Veterans' Home. Such facilities were added to the Appleton plant in 1941.

It is of interest to note that the earliest filter plant installation was that at Oshkosh in 1895. The original plant was completely replaced in 1917. The next oldest plant, still in service, is the slow sand plant at Ashland, which was built in 1896. The Merrill and Marinette circular wood filter units, also still in service, were constructed in 1898 and 1900, respectively. At the time these plants were erected all of the aforementioned utilities were privately owned. The first municipally constructed purification plant was that of South Milwaukee in 1911. The latest of the filtration plants, that of the Badger Ordnance Works, which also serves Badger Village, was completed in 1943. The largest and latest municipally owned purification plant installation, which was completed in 1939, is at Milwaukee.

Quality of Supply Sources

The chemical quality of the supplies from the different sources varies ma-

terially. The hardness of the waters ranges from a recorded minimum of 28 ppm. for the Wisconsin River at the time of the spring runoff to a maximum of 187 ppm. for the Fox River at Neenah during the late winter months. Lake Michigan water averages around 130 ppm. in hardness, which is considerably higher than the water of Lake Superior, which has a hardness of 40 to 50 ppm.

The alkalinity of the supply sources varies with the hardness. Low alkalinities coupled with high color have caused complications in some instances, but generally the alkalinity is sufficiently high in all waters to provide for complete reaction with the coagulating agent.

The color of water ranges from a normal of less than five standard units in Lake Michigan water to a maximum of about 300 units in Wisconsin and Prairie River waters.

Turbidity ranges from a minimum of less than 5 ppm. in most supplies to a maximum of over 1,000 ppm. in a few supplies. Generally the turbidity of the various sources of supply will be less than 10 ppm.

Odors in the surface water supplies of Wisconsin are generally due to algae growths, no supply being entirely free from such troublesome conditions. Odor problems due to algae are most acute in the supplies obtained from Lake Winnebago and the Fox River. Application of activated carbon at rates in excess of 300 lb. per mil.gal. is not uncommon with maximum application of approximately 500 lb.

A number of supplies along Lake Michigan have in the past been troubled with phenolic tastes and odors. Use of ammonia and the cessation in operation of a chemical plant in the Milwaukee area have practically eliminated all objectionable conditions of this nature. Sulfur type odors, originating with wastes from paper pulp mills, are pronounced in the Wisconsin River supplies during the winter months when the stream is covered with ice. Heavy doses of carbon are needed to control the situation.

The bacteriological quality of the raw water of all but one of the developed surface water supplies is well within the limiting coliform index of 20,000 per 100 ml. (Phelps) specified by Streeter as amenable to treatment by accepted purification processes comprising pre- and post-chlorination, coagulation, sedimentation and filtration. Many of the supplies seldom exceed a coliform index of 1,000 per 100 ml. and the average monthly indices of all but a few supplies fall below this value. The raw water index at Appleton, however, frequently is more than 100,000 and recently a monthly average index exceeded 52,000 per 100 ml. Notwithstanding the high raw water index, the treated water easily met the U.S.P.H.S. Drinking Water Standards. The Appleton plant includes lime softening in conjunction with the purification processes previously enumerated. In addition it is blessed with an unusually large sedimentation basin and with enough filter units so that they are able to operate at one-half their rated capacity.

Water-Borne Disease

No discussion of surface water supplies would be complete without some mention of their relation to water-borne disease. There is no doubt in the minds of capable water plant personnel that ineffectively treated sewage-polluted waters have in the past caused much sickness and death; and

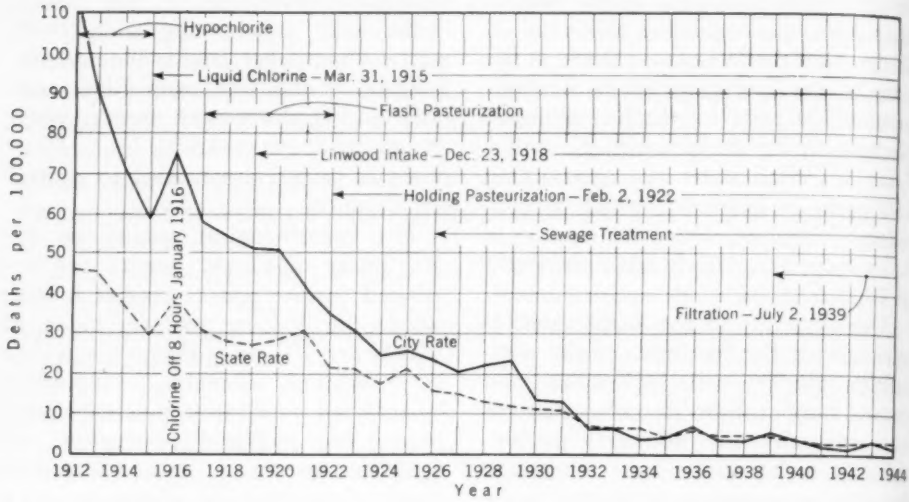

FIG. 2. Reduction in Death Rates—Diarrhea and Enteritis—Children Under Two Years of Age—Milwaukee, Wis.

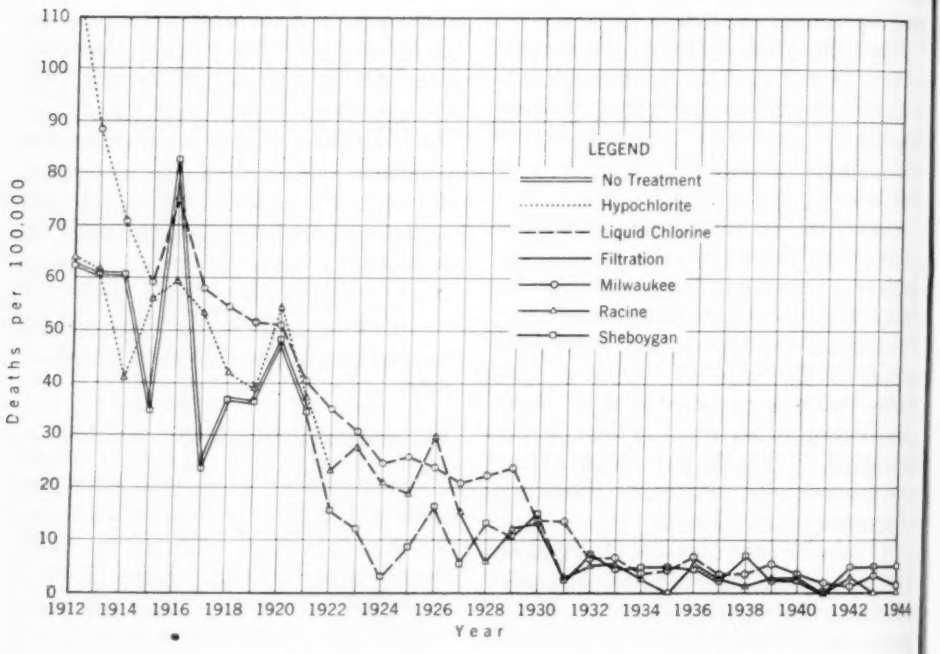

FIG. 3. Relation Between Water Purification and Diarrhea-Enteritis—Children Under Two Years of Age

they will do so again unless plant personnel is always alert and perpetually on guard against pathogenic organisms.

The role of water purification in bringing about a reduction in waterborne diseases was covered in detail in an unpublished paper by Warrick and Muegge in 1932. Time did not allow continuation of such studies; however, a portion of the data was brought up to date. These data, covering diarrhea and enteritis deaths of children under two years of age, are graphically presented by Figs. 2 and 3. Figure 2 shows the reduction in diarrhea and enteritis deaths from 1912 through 1944 for the city of Milwaukee in relation to major sanitary developments. A reduced death rate was brought about by each major improvement in environmental sanitation. Figure 3 depicts the reduction in death rates in relation to water supply improvements for Milwaukee, Racine and Sheboygan over a similar period. This chart further verifies the marked relation between water quality and public health.

Typhoid fever death rates have been reduced similarly by progress in safe water supply development. The death rate is now so low in most communities that it can no longer be used as a measure of progress. Suffice it to say that since 1929 no typhoid fever deaths have been attributable to the unsatisfactory quality of public water supplies.

Our goal should be the elimination of all deaths resulting from water- or filth-borne disease organisms. The last few deaths standing between us and a perfect record in disease prevention will be as hard to avoid in a less than perfectly clean community as will be the removal of the last vestige of water from an imperfectly cleaned glass.

Water Treatment Problems From the Public Health Viewpoint

By E. S. Hoyt

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Presented on Oct. 23–25, 1945, at the Ohio Section Regional Meetings, Findlay, Wilmington, Athens, Massillon, Ohio

THERE are three problems which seem to be of special interest to operators, managers and designers of water treatment plants in Ohio.

The first of these problems has to do with the present organization of the Sanitary Engineering Division of the State Health Department, particularly with regard to the district engineers and their functions. The second problem concerns the approval of plans for water treatment plants, particularly with regard to equipment specifications. The third relates to the present attitude regarding the necessary time of settling in the pre-treatment of surface water supplies.

Organization of Sanitary Engineering Division

The Ohio Department of Health is charged by law with certain duties which are largely delegated to the Division of Sanitary Engineering. These duties may be briefly outlined as follows:

1. The approval of plans for proposed new installations and changes in existing water supply, sewage, purification or treatment works for all political subdivisions of the state and practically for all purposes except water and sewage for private residences and for industrial purposes not intended for human consumption.

2. The approval of plans for proposed industrial waste disposal.

3. General supervision of the disposal of sewage and industrial waste and works for the collection, treatment and disposal of the same.

4. The study and investigation of streams, lakes and other bodies of water for the purpose of determining the uses of such waters, the causes contributing to the pollution thereof, and the effects of such pollution, and recommendation of means for preventing and correcting their pollution so as to prevent damage to public health and welfare.

5. Investigation of statutory complaints of pollution.

6. Investigation of statutory complaints of impure water supply.

7. General supervision of the operation and maintenance of public water supplies and water works systems. One section of the law specifically requires that all water supplies shall be examined once each year.

8. Investigation and reports on safety or adequacy of public water supplies upon initiative of the Director of Health.

In addition to the above, the Sanitary Engineering Division is charged with milk and food sanitation, approval of plans for swimming pools, the elimination of cross-connections, supervi-

sion of sanitation and water supplies for roadside parks and watering points for railroads and other common carriers. These are specifically matters of law; that is, they are duties which the law specifically places on the Division of Engineering. This is by no means the whole list; in their capacity as public servants members of the division are responsible for innumerable minor problems connected with the work.

It should be emphasized here that the disposal of sewage and industrial waste is inextricably bound up with the problem of water supply and treatment. An outstanding example of this is the taste and odor problem resulting from synthetic rubber waste. The need of the synthetic rubber program has been so acute that many have withheld their complaints of tastes and odors in recognition of this war necessity. The elimination of these tastes and odors is very difficult; obviously it is better to try to eliminate the trouble at its source rather than at the many water plants which may be affected. It is because water treatment and wastes treatment are so interrelated that water works men should give considerable thought and energy to projects involving sewage and industrial waste treatment.

Plant Improvements

The law requires that plans for plant improvements be approved by the State Department of Health. Numerous complaints have been received from plant operators to the effect that their equipment is not rendering the proper service, even though it was approved by the department. Anyone who is familiar with working drawings for the construction of a water treatment plant realizes that plans do not tell the whole story; they must be implemented by specifications.

The Department of Health does not wish to cover all the details or to foster any preference of one manufacturer over another. It does, however, want to avoid the installation of unsuitable equipment. For instance, chemical feed equipment must have a feeding range fitted to the demands of the plant in which it is installed. Under some circumstances the installation of a gas feed chlorinator may be absurd, while in other locations the use of a hypo-chlorinator is equally absurd. Yet errors of this kind have been made and some plants are even now struggling under such handicaps.

It is the present policy of the Division of Engineering to refuse to consider plans offered for approval unless such plans are accompanied by adequate specifications and by the necessary design data. If speedy approvals are desired the operator can help by insisting that the specifications and design data come in with the plans.

Settling Time

The third problem concerns the time of settling ahead of filtration in water treatment plants treating surface water supplies. The Ohio Department of Health stipulates a minimum of 4 hours' settling time. Some engineers and some manufacturers have advocated settling periods as low as 45 minutes to 90 minutes where vertical flow sludge blanket treatment is used. In those plants which are treating well water supplies which are not subject to the danger of contamination, pre-treatment periods as low as 2 hours may be considered satisfactory, but where the lime treatment is intended to effect bacterial purification as well as softening, 4

hours, during which causticity is maintained, is the minimum which can be considered satisfactory.

Studies by Hoover, Streeter, Scott and McClure, Edwards, Bahlman, and Van Arnum, beginning about 1908, have indicated the bactericidal action of lime in water treatment. The results of studies of the bactericidal efficiency of lime have been reported by Wattie and Chambers at Cincinnati (Jour. A.W.W.A., **35**: 709 (1943)). This article carries references to previous studies and, in general, gives an excellent summary of the known findings regarding lime purification. As a direct result of all these studies and findings, it has been concluded that not less than 4 hours' exposure to a pH of about 10.5 or higher is necessary where the lime treatment is to be depended upon for purification. The Department prefers to have about 25 to 30 minutes of mixing and flocculation in addition to the 4 hours' settling time.

Where a surface water is to be treated by coagulation, such as with alum or iron followed by filtration, a minimum of 4 hours' pre-treatment is also necessary.

Members of the Division have been asked why they are unwilling to accept the use of the short-period sludge-blanket type of treatment followed by chlorination. Their reason for opposing this is because in such cases the purification depends upon the chlorine, and they are opposed to the use of chlorination as the prime purification process for a public water supply. Ordinary chlorination should be used only as a true safety factor.

Let us consider a water supply that is polluted or potentially subject to contamination. Some effective barrier must be interposed between that supply and the consuming public. Chlorination as ordinarily practiced is a brittle barrier in that it may be broken by failure of a machine, by lack of proper operation or by sudden changes in the raw water supply. Such a barrier if broken is completely useless until it is restored.

Now let us consider a defense in depth, such as (1) a lime treatment purification plant, or (2) a coagulation and filtration plant, or (3) for some well waters that are uniform in characteristics and never turbid, a high-rate chlorination treatment including a retention basin, plus post-chlorination. Such defenses are certainly much less brittle. Ordinary post-chlorination in such treatments is a true safety factor. It is recognized that chemical feed devices may fail, operators may be careless or other mechanical failures may occur, but the complete breakdown of the defense is not instantaneous. Some degree of protection is afforded by the time element and by dilution with the waters in the process, and the secondary line of defense by ordinary chlorination is still effective.

The author believes that it is also worthy of note that, in general, those plants which have ample pre-treatment time ahead of the filters are definitely more trouble-free than those where, by design or overload, the pre-treatment time is shortened to 2 hours or less. This is not a condemnation of sludge-blanket type of treatment; such treatment definitely has its place, but in the treatment of surface water supplies and water subject to contamination, it should be used only in lieu of mixing and flocculation and should be followed by sufficient plain settling to bring the total pre-treatment time up to at least 4 hours.

Colorimetric Determination of Iron in Water With o-Phenanthroline

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A contribution to the Journal

THE use of *o*-phenanthroline for the colorimetric determination of iron has been studied by Saywell and Cunningham (1), Hummel and Willard (2), Fortune and Mellon (3), Woods and Mellon (4) and Mehlig and Hulett (5). The method is sensitive to small concentrations of iron, and standards may be prepared which are stable for a period of four months. The method is based on the reaction between *o*-phenanthroline and ferrous iron (pH range 2.0–9.0) to form a highly colored, orange-red, complex ferrous *o*-phenanthroline which is quantitatively proportional to the amount of iron present in the sample.

Since the reaction involves ferrous iron it is necessary to reduce the iron from the initial evaporation of the sample to the ferrous state. Hydroxylamine hydrochloride has been found to be the most satisfactory for this purpose, and it can be obtained iron-free. The pH is adjusted to 4.0 by the addition of sodium acetate, using Congo red indicator paper.

Reagents

1. *Standard iron solution.* Dissolve 0.7022 g. of crystallized ferrous ammonium sulfate [$FeSO_4.(NH_4)_2SO_4.6H_2O$] in 50 ml. of distilled water and 20 ml. of concentrated sulfuric acid. Dilute to 1 liter; 1 ml. contains 0.1 mg. iron.

2. *Hydroxylamine hydrochloride.* Dissolve 10 g. of hydroxylamine hydrochloride in 100 ml. of distilled water. To reduce 1 ppm. of iron completely from Fe^{+++} to Fe^{++}, 0.1 ml. of above solution is required.

3. *Sodium acetate.* Dissolve 80 g. of sodium acetate in distilled water and make up to 1 liter.

4. o-*Phenanthroline solution.* Dissolve 0.5 g. of *o*-phenanthroline in 50 ml. of ethyl alcohol and dilute to 100 ml. To produce a maximum color with 4.0 ppm. of iron, 1 ml. of this solution is required.

Procedure

Transfer 100 ml. or less of the sample to an evaporating dish. Add 1 ml. of 3N. hydrochloric acid, and evaporate to dryness on the water bath. With silt-bearing waters it is often necessary to use as much as 5 ml. of concentrated hydrochloric acid to effect solution of the iron. When excess acid has been used it is desirable to drive it off, after evaporation to dryness, by heating. Cool the dish and add 1 ml. of 3N. hydrochloric acid (it is sometimes possible to effect solution of the iron by merely adding the acid and boiling). Warm on the water bath and contact

the sides and bottom of the dish with a glass stirring rod. Avoid evaporation to dryness by adding small quantities of distilled water; filter at this point if necessary. Add 1 ml. of hydroxylamine hydrochloride solution, dilute to approximately 25 ml. and add 1 ml. *o*-phenanthroline solution. Titrate with sodium acetate solution in the presence of Congo red indicator paper until the acid is neutralized. Transfer the solution to a 100-ml. Nessler tube and dilute to the mark with distilled water if visual methods of comparison are to be used. The solution should stand at least 30 minutes to be sure all the iron has been converted to ferrous *o*-phenanthroline complex. Compare with standards.

TABLE 1

Ions Interfering With Ferrous o-Phenanthroline Reaction Effect of Cations*

Ion	Maximum Concentration—ppm.	Maximum Interference—% Fe	Applicable pH Range
Aluminum	500	None	2.0–3.0
Aluminum	250	1.4	2.0–5.0
Ammonium	500	None	2.0–9.0
Calcium	500	None	2.0–9.0
Copper	10	None	2.5–4.0
Lead	500	None	2.0–9.0
Magnesium	500	None	2.0–9.0
Manganese	500	None	2.0–9.0
Potassium	1,000	None	2.0–9.0
Sodium	1,000	None	2.0–9.0
Tin	20	None	3.0–6.0
Zinc	10	None	2.0–9.0
Effect of Anions			
Carbonate	500	None	3.0–9.0
Chloride	1,000	None	2.0–9.0
Cyanide	10	2.0	2.0–9.0
Fluoride	500	1.6	4.0–9.0
Iodide	500	None	2.0–9.0
Nitrate	500	None	2.0–9.0
Nitrite	500	None	2.5–9.0
Phosphate (as P_2O_5)	20	1.4	2.0–9.0
Pyrophosphate	50	1.0	6.0–9.0
Silicate	100	None	2.0–4.5
Sulfate	500	None	2.0–9.0
Sulfite	500	None	2.0–9.0

* From work of Fortune and Mellon (3).

TABLE 2

Comparison of Procedures for Determination of Iron in Water Source: Well Waters Collected in California†*

Sample No.	Iron—ppm. Thiocyanate	Iron—ppm. o-Phenanthroline
1	0.21	0.22
2	0.66‡	0.57
3	0.42	0.38
4	0.19	0.11
5	0.06	0.09
6	0.32	0.34
Average	0.31	0.29

* Samples evaporated with acid then dissolved in acid; tests made with Fisher Electrophotometer.

† For detailed analysis, see Table 3.

‡ Red color of ferric thiocyanate contaminated with yellowish tinge, due possibly to interference from nitrate ion present in sample.

Prepare standards by measuring 0.05, 0.1, 0.3, 0.5, 1.0, 1.5 and 2.0 ml. of the standard iron solution into 100-ml. Nessler tubes and treating with the same procedure as for the unknown. The iron content of the unknown is obtained from the standard having the color nearest to it by the formula:

$$\frac{\text{ml. standard iron} \times 100}{\text{ml. of sample}} = \text{ppm. Fe}$$

If photometric comparisons are made, a final dilution of 50 ml. is suggested for the average work where cell depths of 20 mm. and 40 mm. are used. A wavelength of 510 mμ will be found suitable. Blanks should be prepared in exactly the same manner as for the unknown.

Discussion

The determination of iron by *o*-phenanthroline has been studied extensively and has found many applications in various fields of chemistry. For-

TABLE 3

Chemical Analysis of Water Samples Used in Iron Test (Table 2)

Analysis	Sample No.—*ppm.*					
	1*	2†	3†	4‡	5§	6‖
Sodium and Potassium (Na)	19	55	15	3.4	217	45
Magnesium (Mg)	45	13	15	7.5	96	36
Calcium (Ca)	37	48	45	61	163	133
Chloride (Cl)	48	71	70	27	256	168
Sulfate (SO_4)	88	28	27	44	657	90
Bicarbonate (HCO_3)	251	199	99	130	278	310
Total Alkalinity ($CaCO_3$)	206	164	81	107	228	254
Total Dissolved Solids	494	432	330	264	1727	897
Total Hardness (Calc.) ($CaCO_3$)	328	174	177	183	807	448
Nitrate (N)		5	5			
Manganese (Mn)	0	0	0	0	0	0
Silica (SiO_2)	35	35	35	24	40	30
Turbidity (Unfiltered)	5	8	5	6	15	8
Color (Unfiltered)	5	0	0	5	0	0

* Well near Watsonville, Calif.
† Well near Point Montara, Calif.
‡ City supply, Santa Cruz, Calif.
§ Well near King City, Calif.
‖ Well near Castroville, Calif.

tune and Mellon (3) have made a critical study of various factors which may affect the formation of the colored ferrous *o*-phenanthroline complex, including a study of the effect of varying concentrations of 55 ions likely to be encountered in routine analysis. None of the ions commonly found in natural waters interferes with the color production. The method is also applicable to many waters which are highly polluted with mineral industrial wastes, as would be indicated by Table 1, taken from the work of Fortune and Mellon (3), which shows interfering ions frequently encountered in water analysis.

The *o*-phenanthroline method is ideal for visual comparisons in Nessler tubes. Beer's law is obeyed in concentrations as high as 10 ppm. of iron. Permanent standards may be prepared and concentrations up to 2 ppm. are easily read in the standard 100-ml. Nessler tube. The color produced by the ferrous *o*-phenanthroline complex is more intense than that of the ferric thiocyanate complex. This fact has been established in terms of extinction coefficient. The extinction coefficient of ferrous *o*-phenanthroline color is about 12,000, whereas that of the ferric thiocyanate is about 8,000. In other words, low concentrations of iron can be more accurately matched by the *o*-phenanthroline method because of the greater color intensity. There is considerable color even at concentrations as low as 0.05 ppm. of iron.

Many laboratory technicians prefer to concentrate the samples by boiling in the presence of acid rather than by evaporating on the water bath. A number of check determinations have been made using both procedures and the results were decidedly in favor of evaporation. This held true with the

TABLE 4

*Comparison of Procedure for Determination of Iron in Water**
Source: Allegheny River Water at Nadine, Pa.

Sample No.	Iron—ppm. Thiocyanate	*o*-Phenanthroline
1	0.65	0.64
2	1.00	0.90
3	3.30	3.10
4	2.57	2.20
5	2.90	2.66
6	2.65	2.44
7	1.90	1.56
Average	2.14	1.93

* Samples evaporated with acid then dissolved in acid; tests made with Coleman Universal 11 Spectrophotometer.

TABLE 5

*Comparison of Procedure for Determination of Iron in Water**
Source: Allegheny River Water at Nadine, Pa. Treated and Filtered

Sample No.	Thiocyanate	*o*-Phenanthroline
8	0.06	0.05
9	0.04	0.05
10	0.25	0.24
11	0.17	0.18
12	0.20	0.22
13	0.20	0.20
14	0.09	0.07
15	0.08	0.11
16	0.33	0.30
Average	0.16	0.16

* Samples evaporated with acid then dissolved in acid; tests made with Coleman Universal 11 Spectrophotometer.

thiocyanate as well as with the *o*-phenanthroline method. Of 6 water samples collected in California and 39 samples collected from the Allegheny River in Pennsylvania, the average iron results were 15 to 20 per cent lower when the boiling procedure was used.

Numerous iron determinations have been made for the purpose of comparing the *o*-phenanthroline with the thiocyanate method. Table 2 shows the results obtained on six different waters collected in California. Table 3 lists the chemical analysis of each sample. Tables 4 and 5 include comparative iron determinations made on samples of river water in Pennsylvania before and after treatment.

Over a period of three years, comparative tests made on Allegheny River water would indicate that results with the *o*-phenanthroline method are approximately 10 per cent lower than with the thiocyanate method. This does not necessarily mean that the *o*-phenanthroline test is in error because there are many factors that can interfere with the thiocyanate test, and the thiocyanate test therefore should not be considered as a final standard.

Acknowledgment

The authors wish to acknowledge with appreciation the valuable assistance of Mr. William O. Jacobs, laboratory technician, Pennsylvania Water Co., Wilkinsburg, Pa.

[*Editor's Note:* The original experiments with the use of *o*-phenanthroline were performed in 1940 by Mr. Caldwell. Since that time, the authors have been experimenting further with this procedure, and the foregoing is a report of their completed work.]

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Flow of Water in Pipes

By Donald E. Stearns

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WITH his time largely devoted to problems of maintenance and service, the water works superintendent must depend on the practicing engineer to furnish him with a sound, direct and practical approach to such flow studies as he is able to make in an effort to keep his distribution system in proper operating condition. Periodic, systematic check-ups, involving a minimum of time, can then be made and a continuous record kept, which should prove more and more valuable through the years.

Hydrant Flow Tests

A common method of determining the condition of a water main is the use of a hydrant flow test. The quantity of water flowing at a hydrant is measured and the residual pressure at an adjacent hydrant, as well as at a hydrant at the extreme end of the main being tested, is recorded. Such tests are widely used by the National Board of Fire Underwriters to determine the adequacy of water systems for fire protection. Although some superintendents have employed such tests to study the flow characteristics of pipes in their distribution systems, often the condition of a section of pipe taken from a main, or the appearance of the interior of a core cut from a pipe, is taken as indicative of the condition of the entire section of main. The author can recall an occasion when conclusions were drawn on the basis of the appearance of a small core cut from a pipe. These conclusions later proved to be 150 per cent in error because of head losses due to friction.

Hydrant flow tests are not difficult to make and consist of measuring the pressure at a flowing hydrant, either by attaching a pressure gage to a tapped cap on the hydrant or by the use of the pitot tube, which may be held in the stream of water flowing from the hydrant. In both tests it is essential that the gages give accurate readings and that the graduations be to the nearest pound of pressure. Although the readings by either method of testing may be somewhat alike, it is significant that the test employing the pitot tube converts the actual velocity head of the stream into equivalent pressure head, as read on the gage, while a pressure gage attached to the hydrant cap does not reflect any exit losses as the water leaves the open hydrant nozzle, or any velocity head within the hydrant barrel. While the latter omission may be very small, it is significant that some hydrants have very rough edges on the nozzle. Thus, the pitot tube should give a more accurate measure of the actual velocity head of the water as it leaves the hydrant nozzle.

Tabular values of hydrant flows for various sizes of hydrant nozzles are in common use and may be employed readily in converting pressure gage readings at the flowing hydrant to flow in gallons per minute. A theoretical relationship of this flow is readily derived, making use of the fundamental hydraulic relationship, $V = \sqrt{2gh}$, where V is the velocity of the jet of water in feet per second, g is the acceleration due to gravity, and h is the head of water found by multiplying the gage pressure by 2.31 ft. The latter is the height of a column of water, 1 sq.in. in cross-section, that would produce a pressure of 1 psi. The theoretical discharge in gallons per minute may be found by multiplying the velocity by the area of the hydrant opening and may be written as $29.9 \times d^2 \times \sqrt{p}$, where d is the inside diameter of the pipe in inches and p the pressure on the gage in pounds per square inch. A coefficient of discharge equal to 0.90 will allow for the reduction of area through contraction of the jet of water as it leaves the nozzle and for frictional losses through the jet. The product of these two losses is termed the coefficient of discharge. The final relationship may be written as $26.9 \times d^2 \times \sqrt{p}$. The figure 27 is often substituted for 26.9 with no appreciable error.

Care must be taken to measure the hydrant nozzle accurately, because many times hydrant nozzles, even of the same make, vary in diameter. It is significant that a difference in diameter of $\frac{1}{16}$ in. will affect the area of a jet by as much as 5 per cent, and accordingly change the flow results by a corresponding amount.

When hydrant flow tests are being made, to determine the adequacy of a given water distribution system for fire protection purposes, a residual pressure (system pressure) is taken adjacent to the point of discharge, generally at another hydrant not located on the main that is supporting most of the flow to the flowing hydrant. When testing a main for head loss, it is important that residual pressure readings be made at the ends of the main being tested, and that flow into the main be in one direction only. During the period of the test, it is essential that readings taken on the residual pressure gages be synchronized with readings on the pitot tube. A convenient method is to synchronize all watches used by the observers on the test, and to take readings every minute for a period of, say, 5 minutes. This duration will permit the flow in the main to become established and will make it possible to select the proper reading for each of the gages.

Computation of Head Loss

Having performed a hydrant flow test and having recorded residual pressures at points at each end of the main to be tested, the next step is to compute the head loss for the main. This can be accomplished by an application of the so-called Bernoulli Theorem, which states that the sum of the velocity head, pressure head and elevation head at the point most remote from the flowing hydrant is equal to the sum of the velocity head, pressure head and elevation head at the hydrant nearest the flowing hydrant, plus the loss incurred between the two points on the main. In other words, stock can be taken at the position of each of the two residual gages and the difference in the combined head at these two points will reflect the actual head loss due to friction in the pipe. Since a main being tested would have the same diameter throughout its length, the head due to

velocity will be the same at the position of each of the gages, and therefore can be eliminated in determining the head loss. Elevation head will consist of the actual elevation of each residual pressure gage above any selected datum, while the pressure head will consist of the actual gage reading divided by 0.434, the weight in pounds of a column of water 1 sq.in. in cross-section and 1 ft. in height. After the head loss in the pipe has been determined, it is possible to find the loss per 1,000 ft. of pipe, the unit frequently used in tables, by simply dividing by the number of 1,000-ft. units in the section of pipe being tested. It is then a simple matter to determine the actual C value by the use of either the Hazen-Williams tables or the Hazen-Williams slide rule.

Having determined the value of C for the pipe, it is now in order to interpret the results and see what the main is capable of doing. When designing a new main, it is customary to use a value of $C = 100$ for cast iron, and values both above and below 100 for pipes made of other materials. In using this value, allowance for reduction in carrying capacity over a period of years is made at the outset, in order to give the pipe a useful design life. It is convenient to compare the present-day C value of the pipe with a value of, say, $C = 100$, when interpreting the test results. Table 1 expresses the head loss in the pipe in terms of the percentage loss of head for values of C from 40 to 120.

If the main, as it was originally laid, had a C value of 120, then a present-day C value of 70 would indicate that the head loss is now 194 ÷ 71, which is 273 per cent of what it was at the outset, or 194 per cent of that for a C value of 100.

Proper interpretation of the results of flow tests is important, for if the main is a supply main from a pumping station or other source of supply, head losses will have a very direct bearing on pumping head, proper pumping efficiency, power costs, and, if gravity is used, available supply. On the other hand, if the main is a part of a distribution system, it is important to consider its relation to other mains in interpreting the effect of increased head loss. If it is a supply main, the cost of a new main, where the supply is pumped, can be met in part by the capitalized cost of power savings due to a decrease in pumping head and the possibility of operating the pumps at a higher point on the efficiency curve.

TABLE 1

Head Loss Relative to Loss for $C = 100$ (Taken as 100 Per Cent)

Value of C	Head Loss, %
120	71
110	84
100	100
90	122
80	151
70	194
60	258
50	362
40	544

Flow Distribution Studies

When considering the effect of head loss in a main in a distribution system, the author favors the use of flow distribution studies. Replacing the main may be a difficult and expensive task, since the street in which the main is laid has probably undergone many changes since it was installed, and it is a costly undertaking to replace high-grade paving. For this reason, the replacement of mains must follow careful studies if both economy and a maxi-

mum of support to the distribution system are to be effected.

Any flow study, if it is to be useful, must depend upon the present-day condition of individual mains. For this reason, flow studies on mains are absolutely necessary, regardless of the method used in carrying them out. Without such up-to-date data, any flow study must depend upon assumed values of C, on the basis of age of pipes in the distribution system. These values are usually bad guesses and may be very much in error.

The author recalls a case where a 16-in. supply main, 3 miles in length, was assumed to have a C value of 100. Actual flow tests showed that the main had a C value of 82, and that the pumping head was 15 lb. in excess of what it would have been at $C = 100$. In this case, it was not possible to deliver sufficient water during periods of high draft to keep standpipes that floated on the system filled. Studies showed that either supplementing the main with another pipeline, which could act as an auxiliary line, replacing the main, or cleaning and lining of the present main, was essential to proper operation. In this case additional storage would not have been a solution to the problem, although tentative plans had been made to construct such additional storage facilities.

In making flow distribution studies, whether the superintendent makes them himself or engages outside assistance, there has been a tendency to avoid methods employing the so-called Hardy Cross Method, because of the long, tedious process of getting workable results. The author has tried the various methods, including Fair's adaptation of the Hardy Cross Method, and favors the basic method provided nomographic charts are used for calculations and equivalent pipe lengths of constant size and constant C values are used. Studies made in 1943, by T. Francis O'Connor, of the Sanitary Corps of the U.S. Army (1), have formed the basis of the method used by the author. O'Connor suggested adjusting the C values of all pipes in the system to equivalent lengths of pipes, with $C = 100$. He then suggested further adjustment of the lengths of all pipes with $C = 100$ to a single size of pipe, namely 8-in. diameter. With the entire distribution system made up of a single size pipe and with a constant C value, a single nomographic chart (Fig. 1) may be used. On this chart, the length of pipe, quantity of water flowing, head loss and appropriate values for flow distribution in the Hardy Cross Method may be taken. The use of a single chart makes it possible to carry out all computations, except simple arithmetic, without other aids. This nomographic chart is also useful in reducing hydrant flow test data to find the head loss in a main, although care must be taken to reduce the main tested to the size of pipe shown on the nomograph.

The author found it convenient to make up a new nomographic chart adapted to reducing all pipes to an equivalent size of 12-in. pipe. This chart (Fig. 2) was used to make flow studies on a water distribution system with 135 miles of mains where the prevailing size of mains in the main supply loops was 12 in. All pipes in the feeder loops were reduced to equivalent 12-in. size, with a constant C of 100. The actual time required to make these studies was approximately 50 per cent of what it was on a system of similar size before the method of equivalent size and constant C value was employed. Equivalent lengths expressed as conversion factors to give

TABLE 2

Equivalent Lengths Having Same Friction Loss in 8-in. and 12-in. Pipe

Pipe Diameter in.	8-in. Conversion Factor	12-in. Conversion Factor
4	29.0	
6	4.06	29.1
8	1.00	7.19
10	0.34	2.43
12	0.14	1.00
16	0.034	0.246
20	0.012	0.0829
24	0.0048	0.0344
30	0.0016	0.0116

equivalent lengths of both 8- and 12-in. pipe are given in Table 2.

When conducting flow distribution studies on a water distribution system, it is necessary to reduce the entire system to a series of loops, each loop representing a main supply loop in the system. The more loops, the more involved will be the actual flow studies. Thus, it is desirable to know the system well enough to be able to identify the essential supply loops.

The effect of smaller pipes outside the main supply loops may be determined through the use of equivalent pipes. The nomographic chart is particularly useful for this purpose. The author has found that a photostatic copy of the water distribution system map reduced to a convenient working scale is suitable for this purpose. A pencil tracing is then made from this negative, and the smaller pipes that have small flows and that are capable of having little effect on the study are eliminated. Generally, pipes smaller than 6 in. are neglected. Sometimes as many as three tracings will be required in the process of reducing the system to a workable form.

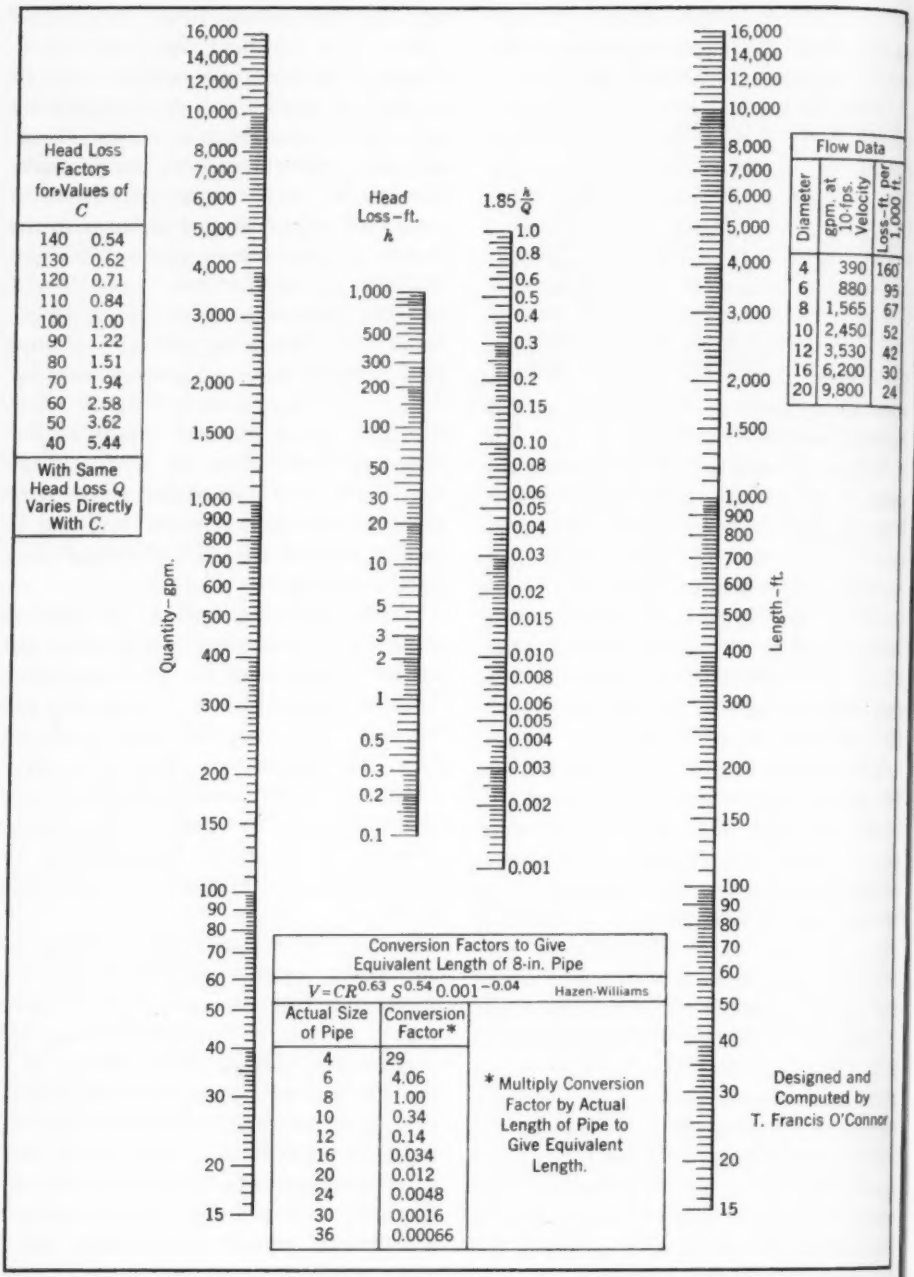
Summary

It is not the author's purpose to explain the method of procedure for carrying out the actual flow distribution study. The excellent paper (1) by T. Francis O'Connor previously referred to does an admirable job of explaining the method of approach. Like O'Connor, the author had occasion to make flow studies on a number of water systems that were installed at bases in the North Atlantic during the war. These systems consisted of new pipe; thus, it was not difficult to determine a proper value of C, knowing the type of pipe used. Many times pipe sizes were reduced to dangerously small sizes through governmental regulations; thus any predictions as to fire flows that might be obtained had to be more than approximations and had to be made without the aid of actual field measurements.

When studying a flow distribution system it is necessary to determine the actual system load for a given study. This is always a difficult task and can at best only approximate whatever flow load might take place at a given time. The structural designer considers himself fortunate if his design computations can be depended on for assumptions within about 3 per cent of error.

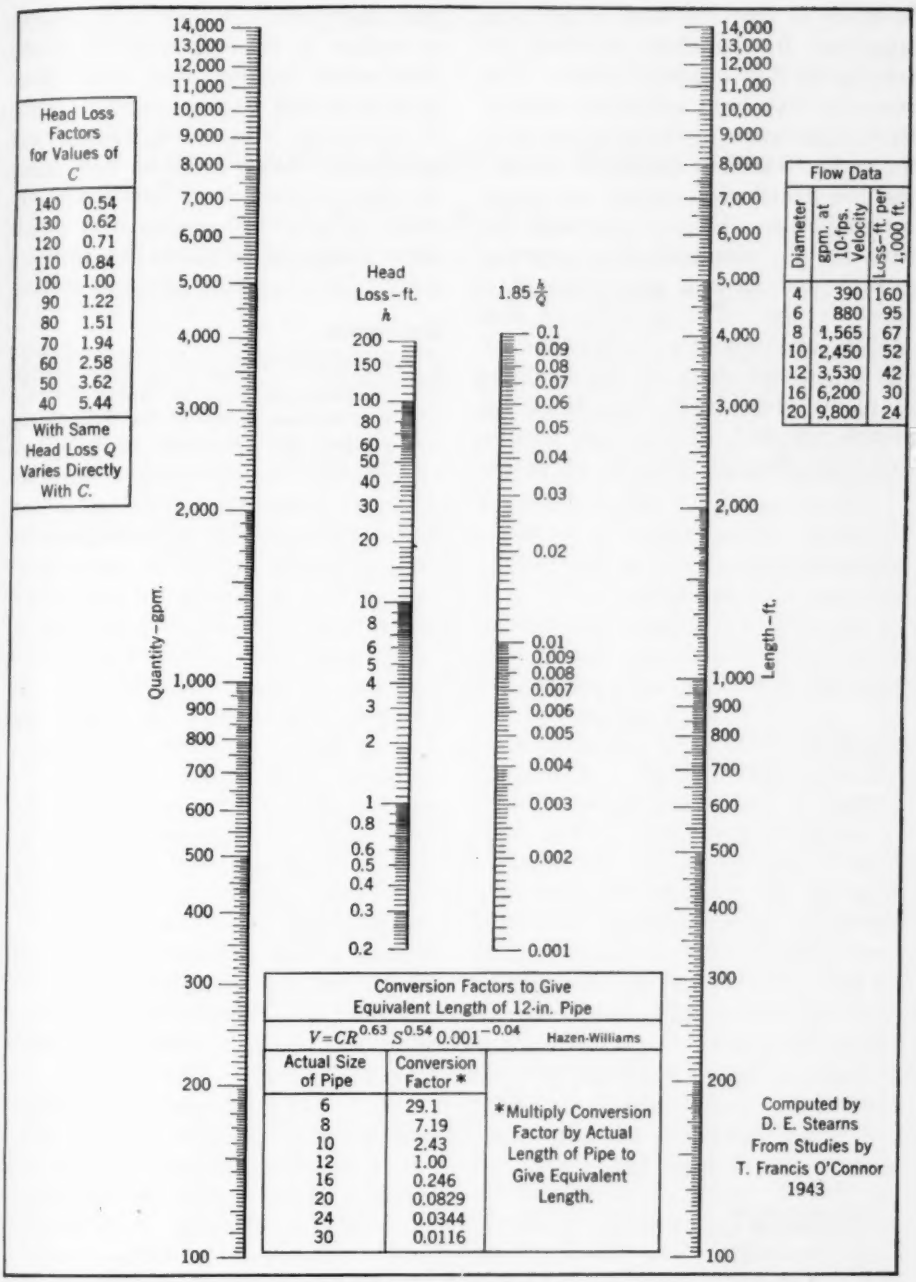
It may be argued that working out equivalent lengths of pipe having the same diameter and constant C value makes the use of flow studies very approximate. The author believes that the studies are entirely consistent with the basic assumptions that must be used and found not over 3 per cent error between predicted pressures on the basis of flow studies by this method and actual observed pressures taken after improvements recommended on the basis of the studies had been made.

No effort has been made here to present detailed information on methods or to introduce new principles.



Adapted from drawing by Fay, Spofford & Thorndike, Engrs., Boston

FIG. 1. Nomograph for Analysis of Flow in Water Distribution Systems—$C = 100$ for 8-in. Pipe



Adapted from drawing by Fay, Spofford & Thorndike, Engrs., Boston

FIG. 2. Nomograph for Analysis of Flow in Water Distribution Systems—$C = 100$ for 12-in. Pipe

Methods of approach have simply been suggested for handling problems involving the flow of water in pipes. The remarks have been addressed particularly to the water works superintendent, for he is the man responsible for keeping the distribution system in proper running order. Most of our water systems are the result of many years of growth and have a great variety of ages of pipe. The problem of flow analysis becomes very cumbersome unless a constant check on the condition of mains and direct methods of approach are used. The author believes that only through the use of proper flow distribution studies is it possible to replace or strengthen mains in the distribution system that will effect greatest benefit to the system in terms of operating costs and capital expenditures. Once a careful flow study has been effected, from flow study records on individual mains, it is possible to make additional studies, utilizing much of the results of previous studies.

Reference

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Construction Costs and Water Rates

By Louis R. Howson

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Presented on May 10, 1946, at the Annual Conference, St. Louis, Mo.

THE water utility in a normal American city is a growing institution. If adequate service is to be maintained, that growth cannot be checked. Over the past couple of decades, the average water works has expended for new construction approximately 28¢ out of every dollar of revenue that it has collected from the consumers. In the latter part of this 20-year period water works construction was curtailed by the war, and accordingly a considerable backlog of work is now awaiting favorable construction conditions.

As of 1946, the costs of operating and maintaining water utilities are rising sharply, and the net income after operations is correspondingly shrinking. In 1945, nearly 60 per cent of the gross revenue was expended for operation and maintenance, leaving but 40 per cent for fixed charges and capital additions. From 1925 to 1945, an amount equivalent to 62 per cent of the net income from operations was invested in new construction.

The chaotic conditions surrounding the construction industry, and the sharply rising costs of labor and materials used by water works, raise the following pertinent questions:

1. How much new capital will be required to finance the normal construction program of water utilities at the prices likely to prevail in the decade following 1946?

2. Will the 1946 water rates provide the funds necessary to operate and maintain the properties and extend them in the future as in the past? or

3. Will it be necessary to increase water rates, and, if so, how much?

As every water works should be self-supporting and self-perpetuating, it is apparent that adequate rates and revenues are essential. It is not too early to appraise the effect of the war and governmental policies on the future of water works.

Construction costs have more than doubled since 1932. They have risen 7 per cent the first four months of 1946, and the end is not in sight.

Every war leaves industrial turbulence and rising costs in its wake. While our emergence from World War II is so recent and the maladjustments arising from the war are so serious that accurate forecast is impossible, a study of the effect of prior wars will assist in charting to some extent at least the probable course which construction costs will take following World War II. There has been a price "spree" during and after all wars. World War II differs from its predecessors only in that there was a 10-year psychological "spree" before the war. Also, in this war the federal government introduced a new element by simultaneously adopting the conflicting economic policies of higher wages and incentive

payments to labor and price curbs or ceilings on commodities. This practice continues.

Such interference by government with economics makes the present a most difficult time to forecast construction costs or to chart future procedure. We must plan and stake our money on the future, however, even though one Washington radio address can upset a whole economy so far as the construction industry is concerned.

Backlog of Construction Plans

In normal times, water works expend approximately $125,000,000 each year for new construction. When V-J Day arrived, plans for nearly $800,000,000 worth of water works construction had either been prepared or were in preparation. There was a total of approximately $24,000,000,000 worth of construction of all types in the design stage at that date. If construction from this vast reservoir of work proceeds normally, it will provide direct work for approximately 3,000,000 men and, indirectly, for many more. Under the conditions now prevailing, much of this work will never go forward; and if costs get too high the public will refuse to pay the prevailing prices, and only the most urgent of the work will go forward at all. This fact can possibly be best illustrated by the housing situation, which, incidentally, is not wholly an outgrowth of the war. During the decade of the thirties, at a time when our federal expenditures averaged twice as much as during the roaring twenties, and when in the 8 years from 1932 to 1940 construction costs increased 55 per cent, there were but one-third as many housing units built as in the prior decade. Numerous recent housing surveys have disclosed that people are thinking realistically about what they can afford for housing, and most people are inclined to postpone building if the house they want is going to cost more than the price they have had in mind.

A similar statement might be made with respect to water works construction. Approximately 80 per cent of all American water works are now municipally owned. Most of them finance their improvements from earnings. Whether publicly or privately owned, if the cost of the improvements mounts too high, those improvements must either be foregone or the rates for water service must be increased sufficiently to cover the increased costs.

History as a Guide

It is possible to draw reasonably accurate conclusions from studies of the effect of prior wars upon costs of living or costs of construction for nearly 200 years back. Beginning with the Civil War period, the data are conveniently at hand. The Civil War resulted in a rapid increase in prices up to approximately 75 per cent above those prevailing just before the war, in 1860, and these prices did not recede until 1873, after which there was a continual recession for a 5-year period. The low point in 1878 was approximately 40 per cent higher than the prices prevailing in 1860.

Similarly, after World War I, prices continued to increase until the summer of 1920, after which there was a period of about 2 years during which both wages and construction costs dropped materially, then recovered to a comparatively stationary plane which was approximately double that of 1913. This level remained quite constant until 1930. In 1930 a second recession began. By 1932, construction costs had

receded to a low point which was slightly more than 50 per cent above those of 1913. Since 1932, construction costs have continued to increase until at the present time they are three and one-half times what they were in 1913 and more than double what they were in 1932.

For comparative purposes, the cost factors during and after World War I and the Civil War and up to the present time with respect to World War II are shown in Fig. 1. It will be noted that due to the curbs or ceilings on material prices during World War II the increased cost of construction above that at the beginning of the war was less in World War II than in either the Civil War or World War I. Since the so-called "labor policy" of the federal government was revealed in the early months of 1946, however, construction costs have risen at an unprecedented rate and are still on the increase. Where the construction costs of the future will lie cannot be definitely predicted except that it can be asserted with reasonable confidence that construction costs will never again be less than 50 per cent above those prevailing in 1939. It is believed that aside from

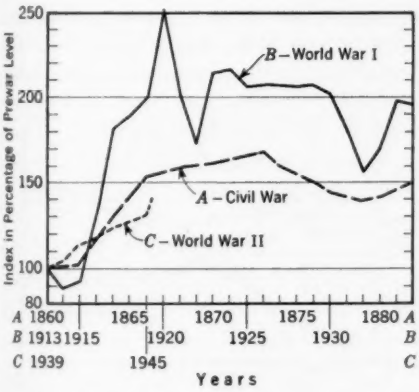

FIG. 1. Effect of War on Construction Cost and Wage Indexes

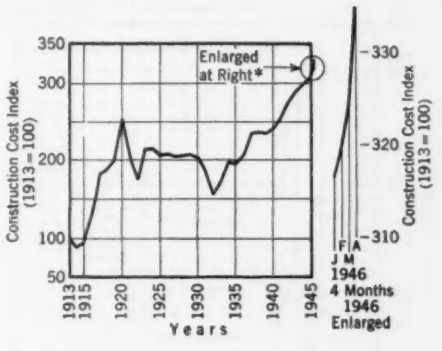

FIG. 2. E.N.-R. Construction Cost Index
* Increase in 1946—6 per cent in 3 months.

minor recessions, possibly the result of too avaricious demands by labor, construction costs of the next decade will average 60 to 75 per cent above those of 1939.

Figure 2 shows the *Engineering News-Record* construction cost index for each month from 1913 to April 1946. It will be noticed from this diagram that the construction cost index is now 62 per cent above what it was in the boom year 1929, and that during the depression years of 1932 to 1940 costs increased 55 per cent. During these 8 years, public-financed construction averaged 40 per cent of the total and but one-third as many houses were built as during the corresponding boom period of the twenties, when public construction averaged only 20 to 25 per cent of the total.

Are Wages Reflected in Construction Cost?

In recent months we have heard many statements, mostly from Washington, to the effect that wages could be materially raised without more than a very minor effect upon price levels. No opinion is expressed herein with respect to the relationship between wages of labor and costs in any other

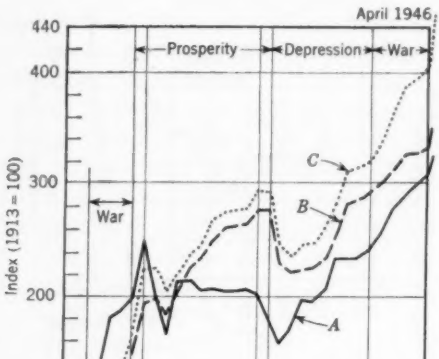

FIG. 3. Relation Between Wage Rates and Construction Costs

A—Construction cost index (1913 = 100).
B—Hourly wage rate, all building trades (1913 = 100).
C—Hourly wage rate, laborers and helpers (1913 = 100).

than the construction industry, but in that industry the relationship is practically a direct one.

Figure 3 shows three graphs: the *Engineering News-Record* construction cost index, the hourly wage rate for all building trades and the hourly wage rate for laborers and helpers—all from 1913 to 1946. Over the 33-year period, the *Engineering News-Record* construction cost index climbed to the extent of 75 per cent of the average percentage rise of common and skilled labor. In the shorter upswing during World War II, that is, from 1939 to April 1946, the construction cost index increased 42 per cent, whereas the average of common and skilled labor increased 34.5 per cent.

This close relationship also exists during periods of decreasing labor and construction costs. For instance, at the beginning of the depression, from 1930 to 1932, the *Engineering News-Record* construction cost index decreased 23.1 per cent, as compared to the average reduction in common and skilled labor rates of 25.2 per cent. In the long upswing from 1932 to April 1946, the *Engineering News-Record* construction cost index rose 114.5 per cent, as compared to the average increase in common and skilled labor hourly wage rates of 103.5 per cent.

The close relationship is further illustrated by Fig. 4. On this diagram the three lines represent respectively the *Engineering News-Record* construction cost index; the cost of 6-in. mains laid in Louisville, Ky., plotted for each year from 1940 to 1945 except for 1944, when so small a footage was laid as not to be representative; and the *Engineering News-Record* common labor wage rate. The points on all curves are plotted with respect to the percentage relationship which each year's cost bears to the cost in the year 1940 taken as 100. During the period covered by this graph, Louisville laid an average of approximately 6 miles of 6-in. mains per year.

These simple graphs and analyses of labor wages—construction cost relationships which could be enlarged indefinitely—should convince the most skeptical that in the construction industry there is a direct reflection of labor rates in construction costs. As

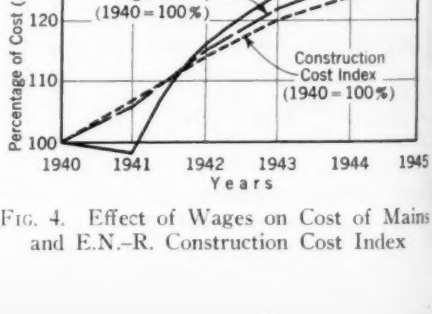

FIG. 4. Effect of Wages on Cost of Mains and E.N.-R. Construction Cost Index

a result of the national labor wage policy there will be fewer and poorer houses built. In the author's opinion, the economic policies which have already increased construction costs 60 per cent above 1929 levels and 115 per cent above 1932 levels do not justify the building of tomorrow's slums today. Neither does he believe that water works, the most vital of all utilities, should have their essential services or expansion curtailed by such policies. But that will be the inevitable result unless water rates are also raised.

Dollars vs. Structures

Practical water works men know that every time 1,000 persons desire new service from the water system, the water works must lay approximately 2 miles of pipe, install 200 services, set 200 meters and add other construction essential to supply the water requirements. The physical structures must be supplied whatever the cost.

Although we have become numbed to the use of astronomical figures, we are still impressed by the statement from Washington that we are planning for a $15,000,000,000 construction industry by 1950. What they should be more concerned with is "How many structures will that build?" It is for the purpose of throwing some light on this picture that Fig. 5 is presented. The upper line of this figure shows the total construction volume as reported in the bulletins of the U.S. Department of Labor. The lower line represents the amount of construction which that expenditure produced, being the dollars expenditure in the upper line divided each year by the *Engineering News-Record* construction cost index (Fig. 2). It will be noticed that the divergence between the two lines has steadily increased since 1932.

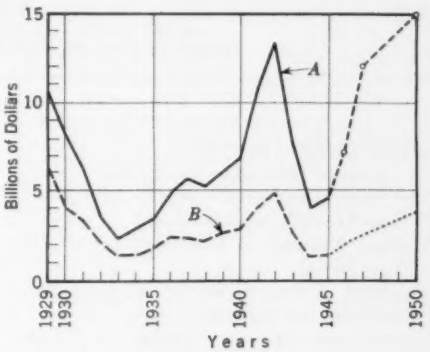

FIG. 5. Total New Construction in the United States

A—Construction volume.
B—Construction volume reduced to 1913 cost index.
o—Department of Commerce estimates.

The extension of the diagram beyond 1945 is based upon government forecasts for the dollar curve and reflects the author's forecast as to construction costs in the lower curve (the construction cost index for 1950 was taken to be 400). It will be noted from this diagram that, although the government's estimates for the dollar value of construction for 1950 are approximately 50 per cent higher than the dollars expended for construction in the boom year 1929, the net result will be only approximately 60 per cent as much construction in 1950 as in 1929. It is structures not dollars in which we are housed, and it is with physical construction that we must supply water consumer needs. When so interpreted, the Washington figures are much less impressive.

Application to Water Utilities

No normal water works is static. Even in communities where population growth has leveled off, demands created by the rising standards for water service require continuing expenditures for new construction. In order

TABLE 1

Growth in Invested Capital of 100 Water Works Plants

	Municipal Plants	Private Plants	Combined Total
Capital Invested in 1925	$141,659,533	$213,293,113	$354,952,646
New Capital Invested—1925–1945	$152,396,225	$ 84,246,899	$236,643,124
New Capital Invested—Yearly Average	$ 7,619,811	$ 4,212,345	$ 11,832,156
20-Year Growth in Capital—%	107+	39.6	66.7
Average Number of Customers Over 20-Year Period	683,794	1,014,926	1,698,720
Weighted Average Annual Capital Expenditure per Customer	$11.10*	$4.15	$7.00
Approximate Average Number of People Served (1925–1945)	4,880,000	4,060,000	8,940,000
Approximate Weighted Average Annual Capital Expenditure per Capita	$1.56	$1.04	$1.34

* High, due to effect of Chicago's high ratio of population to customers (approximately 8.7:1).

to measure the extent to which the capital investment in water works properties has been increasing over the past two decades, the statistics of a hundred water works were studied with respect to the growth in capital investment, the number of customers attached to the system, and the growth in gross revenues and operating expenses. These basic data have been further studied with respect to probable construction costs of the future, the effect of rising costs of operation and maintenance upon net income, and the ability of the water utilities to secure from earnings the funds necessary for expansion.

Growth in Invested Capital

Data available in the author's office relative to the growth in capital investment of a number of water works properties were supplemented by the generous response by the management of both private and municipally owned water works to whom requests were sent for information. Data were requested and furnished with respect to:

1. Undepreciated book costs as of Dec. 31, 1925, and Dec. 31, 1945.
2. Number of customers attached to the system as of Dec. 31, 1925, and Dec. 31, 1945.
3. Gross revenue for 1925 and 1945.
4. Operating expenses before depreciation for 1925 and 1945.
5. Where readily available, the expenditures for operating labor in 1925 and 1945.

The data secured cover the statistics on 100 water works properties serving approximately 1,500,000 customers in 1925 and over 1,900,000 customers in 1945. Of the total invested capital in these 100 plants, which amounted to $591,595,770 in 1945, 49.7 per cent was invested in municipal plants, and 50.3 per cent in privately owned plants. The invested capital had grown from a 1925 level of $354,952,646 or, expressed in dollars per customer, it increased from $238 in 1925 to $310 in 1945.

Although the 1945 total investment was divided almost evenly between municipal and private plants, the number of private plants because of their smaller size made up approximately 9[illegible] per cent of the total number studied

TABLE 2

Operating Statistics of 100 Water Works Plants

	1925		1945	
	Total	Per Customer	Total	Per Customer
Gross Revenue	$39,276,912	$26.15	$61,139,286	$32.10
Operating Expense Before Depreciation	18,979,223	12.70	33,328,177	17.45
Net Income Before Depreciation	20,297,689	13.45	27,811,109	14.65

The growth in the invested capital in these 100 plants is summarized in Table 1. It will be noted that over the past two decades these water works, which represent 100 communities and more than 10 per cent of the total number of people served by public water supplies in the United States, expended annually for new construction an average of $1.34 per capita served. This general average secured from the study of equal investment in private and public plants is undoubtedly low, as the municipal plants with their comparative freedom from taxation have expended more per capita for new construction. As 80 per cent of water plants are municipally owned, including all of the largest cities, it is believed the true average annual expenditure per capita is approximately $1.45. With 80,000,000 people having public water supply service, the water utilities have been expending approximately $120,000,000 per year for new construction. This money was expended when construction costs were much lower than in 1946. To produce the equivalent structures in 1946 would cost approximately $200,000,000; and it is probable this annual requirement will exceed $250,000,000 when the full effects of present labor wage policies are felt.

As an illustration of the comparative growth in invested capital and number of customers, the statistics of these 100 water works show that in the two decades from 1925 to 1945 the invested capital increased 67 per cent while the number of customers increased but 27 per cent, i.e., the investment grew at a rate two and a half times as fast as the number of customers. Clearly, water works are not static nor is their demand for capital simply a reflection of growth in population served. Apparently water works capital requirements are influenced fully as much by developments in methods of treatment, for example, such as filtration, iron removal and water softening, as by community growth.

Water Revenues

The figures relative to the growth in gross revenue and operating expenses are also interesting. Analysis of the operating statistics of the 100 water works is summarized in Table 2. It will be noted that there has been a growth both in gross revenues and in operating expenses before depreciation. Gross revenues per customer registered a gain from $26.15 to $32.10, or 23 per cent in the two decades. Operating expenses too have not been static, increasing from $12.70 to $17.45 per customer, or 37 per cent in the two decades. The net income has remained

relatively constant, being $13.45 per customer in 1925 and $14.65 per customer in 1945, a gain of but 9 per cent. During the same period the invested capital increased from $238 to $310 per customer, a growth of 30 per cent. Obviously the rate of return earned on invested capital decreased during the 20 years.

The gross revenue in 1945 was generally at an all-time peak resulting from the high industrial use occasioned by the war. It is probable that quantity of water sold in the future years will be somewhat less, but so far as figures are available to date, it would appear that 1945 revenues should be maintained due to residential customers taking over part of the industrial water and paying a higher rate for it.

The net income for the 100 plants over the 20-year period from 1925 to 1945 has averaged about $14 per customer per year. The capital additions during the same period averaged $7.00 per customer per year, an amount equivalent to 50 per cent of the net income. The municipal plants studied spent approximately 84 per cent of their net income before depreciation for construction, and the private plants, about 27 per cent. Taken together, public and privately owned water utilities spent 24 per cent of their gross revenue and 50 per cent of their net income before depreciation for capital additions.

Increase in Operating Expenses

Operating expenses have grown more rapidly than income. In 1925, operating expenses took but 48.5 per cent of the gross revenue; by 1945 this had increased to 54.5 per cent.

Operating and maintenance costs in 1946 are rising sharply. It would appear likely that labor costs which constitute roughly 45 per cent of the operating cost of the average water works will follow the "national policy" pattern and be raised about 17.5 per cent within the next few months. Fuel and electric power (electric rate schedules usually carry a fuel clause) constitute approximately 13.5 per cent of the operating expenses of the average water works. As an outgrowth of the present coal strike and the adjustments which will follow its termination, it is likely that the cost of fuel will be raised approximately 10 per cent. Materials, supplies, taxes, etc., which constitute the remainder of the operating expense item, may be expected to increase by approximately 15 per cent. The effect of these already apparent increases on the annual operating cost per customer of water utilities in general is estimated as follows:

Fuel or power at 10 per cent of 13.5 per cent of operating cost	$0.24
Labor increase at 17.5 per cent of 45 per cent of operating cost	1.38
Other materials and supplies at 15 per cent of 41.5 per cent of operating cost	1.08
Total Increase per Customer	$2.70

The total of the increases above estimated as applicable to fuel, labor and other operating supplies, aggregates $2.70 per year per customer, or approximately a 15.5 per cent increase in operating expenses which can be anticipated within the very near future.

This increase in operating expenses will correspondingly reduce the net income so that instead of there being a net of $14.65 per customer as in 1945 there will be but $11.95 net per customer. This $11.95 net income, however, when expended for new construction, will purchase only approximately two-thirds as much as it would have purchased in 1940. Since in the past

50 per cent of the net income of both public and private plants as an average group has been expended for other than new construction, it can be assumed that at least this much, or $7.30 per customer, will be needed in the future, and this assumption will necessarily result in a lower rate of return on capital.

Deducting this $7.30 from the estimated net income of the near future, or $11.95, leaves $4.65 per customer for new construction as compared to the $7.00 spent each year in the last two decades. But $7.00 will not pay for as much construction as in prewar times; to maintain the same volume of construction at costs prevailing post war will require at least $11.20 per customer. Since there will be but $4.65 per customer available, the gross revenues must be increased approximately $6.55 per customer, or in round numbers, 20 per cent above those of 1945 (Fig. 6). This is equivalent to about $1.40 per capita per year.

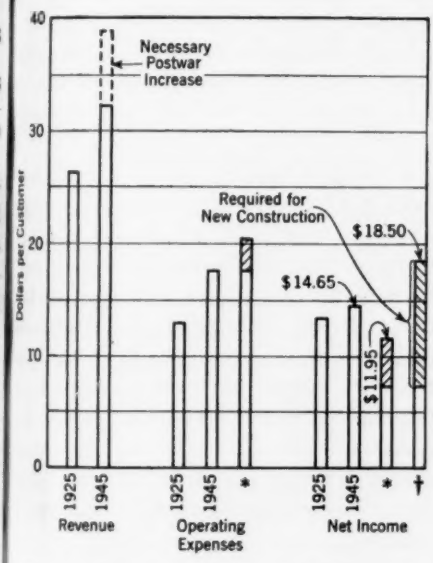

FIG. 6. Necessary Increase in Revenue

* Early postwar estimates.
† Net income nccessary for postwar maintenance.

This year is not too early for each plant management to appraise its individual requirements and status in comparison with the general averages presented herein and start appropriate adjustments.

Construction Costs vs. Construction Cost Indexes

In normal times, the *Engineering News-Record* Construction Cost Index is a valuable and reliable aid in translating costs of one period into estimates for another. However, 1946 is not a normal year. The construction industry is beset by fear—fear of strikes, uncertainty about labor rates and efficiency, inability to secure materials when needed and to contract for materials at a fixed price before bidding, and fear of government- and union-imposed restrictions affecting performance and costs. These all operate to restrict bidding and increase the allowance for contingencies and the total cost. These hazards are not reflected in construction cost indexes. Accordingly, in 1946 it is practically the universal experience of those attempting to let work by contract that the prices bid much exceed those estimated by adjusting prior construction costs according to the construction cost indexes.

Unless these hazards are removed the 20 per cent increase in water rates indicated as necessary by this discussion will have to be materially increased.

Water Compared to Electric and Gas Utilities

In discussing this subject, Linn Enslow, Chairman of the A.W.W.A. Publication Committee, raised a question

which will probably be asked of many Association members, namely, why should it be necessary for water works to have increased rates when many electric companies have reduced their rates since the war? There are numerous reasons for this difference, among the more important being:

1. The per capita use of water increases very slowly, whereas the use of electricity is rapidly expanding. From 1925 to 1945, water works revenues per customer increased but 33 per cent, and part of this reflected rate increases. In the corresponding period the residential use of electricity per customer tripled. The average residential electric bill exceeds $30 per year. The average residential water bill is less than half as much.

2. Water utilities, like houses, are local and individual. Electric utilities are continually developing toward centralized generation and long-distance transmission. Electricity can be transmitted over a high-tension line for a long distance to a city of 10,000 population at a cost of $2,000 per mile of line. If the electric energy is generated in that 10,000 population town by coal it will take approximately 2 lb. of coal per kwhr. When generated in a large central station and transmitted to this city, the energy is available at less than 1 lb. of coal per kwhr. There is no analogous possibility in water works.

3. High-tension transmission has tied in great areas such as that from the Tennessee Valley to the Great Lakes and from the Appalachians to the Mississippi River. This makes available to the Chicago area the cheap hydroelectric power of TVA at times of abundant water supply and surplus generation in the TVA system, and during periods of drought and insufficient water in TVA makes available to that area the steam-generated power from the Chicago super-power development. No such pooling of facilities, which minimizes reserve equipment requirements, is practicable with water works.

4. Water works revenues have always been low compared to electric revenues. In nearly any city, water works revenues are but from 10 to 20 per cent of electric revenues. There is not the latitude in which to work with water revenues that there is with electric revenues. During the war period, some electric plants paid, as excess profits taxes, as much as $10.00 per capita served. No comparable payment by any water works is known to the author.

5. In comparison with natural gas, water is incompressible, an important factor in determining the distance over which it can be transmitted. Gas follows Boyle's Law, and, by compression to high pressures, can be transmitted economically over long distances. Natural gas from Texas is used practically to the Atlantic seaboard.

6. Water works, due to health and fire protection requirements, must maintain reserves not required of other utilities. Gas and electric service may be and are subject to infrequent but nevertheless recurring interruptions. A very large percentage of all the water works systems in the country have not had an interruption in service for decades. As a result water works operate at a disadvantageous "load factor" as compared to gas and electric utilities.

History Repeats Itself

In the April 1925 JOURNAL, the late Leonard Metcalf, Past-President of

the Association, presented a timely discussion titled "Financial Status of Water Works." Mr. Metcalf's discussion was prepared in 1925 and accordingly reflected several years' experience following World War I. He reported that, in the interval from 1915 to 1923, water works gross revenues had increased 57 per cent, of which 20 per cent, or more than a third, was gained by changes in rates. He stated this increase was an important help in enabling water utilities to serve the public adequately, but added, "It may fairly be anticipated then that under average conditions there will be an advance in water rates of at least one-third in the next few years if water works values are readjusted with those in conformity with other property."

Conclusions

From the foregoing discussion, it is believed certain general conclusions can be drawn:

1. The growth of public water supplies must continue. By and large, the funds necessary to sustain that growth must come from revenues for service rendered.

2. Construction costs in the early part of 1946 are about 40 per cent above those of 1939. Aside from minor recessions, it is believed these costs will continue to increase to a general average over the next decade of 60 per cent to 75 per cent above 1939, and even in time of the next depression will not recede to within 40 per cent to 50 per cent above costs prevailing in 1939.

3. Washington's labor policies are in large part responsible for these increased costs. Whatever may be the facts with respect to commodities, it is indisputable that construction costs directly reflect increased wages to labor.

4. At the present time the atmosphere surrounding construction work is so surcharged with uncertainty as to make it impossible to secure satisfactory fixed prices on many types of work. Of the immense backlog of water and sewage works construction awaiting contract, much will be deferred or abandoned.

5. Some public works are being deferred because Washington has not declared itself with respect to federal aid on public works projects. Most cities do not want federal aid, but the possibility that there may eventually be federal participation is a strong deterrent to many cities which otherwise would proceed without it. Washington should declare itself on this matter.

6. Rising costs of operating and maintaining water works will seriously cripple the expansion of water works unless there is an increase in gross revenues of approximately 20 per cent, equivalent to $1.40 per capita per year.

7. Water works management must be alert to its responsibilities to maintain service and make improvements as needed. To make this possible, they must see to it that their rates are so fixed as to provide the funds necessary for needed construction.

The Federal Housing Program

By Harry E. Jordan

Presented on May 10, 1946, at the Annual Conference, St. Louis, Mo.

MUCH of the current discussion concerning housing needs appears to consider the situation as one derived from the war or thrust upon the nation with the return of the soldiers. In a broad sense, that is not true. Deficiencies in the annual rate of housing construction have been developing since the middle twenties. Substantially inferior or "slum" housing has been the concern of American social workers since the middle of the last century.

The war did two things to housing. First, the construction of privately financed housing was practically suspended. The "all-out" war effort left neither materials nor manpower for building houses—except as federal agencies built for war workers. Second, the end of the war concentrated, within a short space of time, the demands of returned servicemen for homes. But it is well to remind these veterans that the homes they want now could not have been built during the war.

In 1940, there were about 36,000,000 dwelling units in the United States, of which 6,500,000 were farm dwellings. Of the non-farm units, 16,000,000 were rental property and 55 per cent of these rented at less than $30 monthly. More than 10,000,000 of the urban dwelling units in 1940 either needed major repairs or were unfit for habitation. From 1920 to 1940, there were 7,000,000 homes built, but by 1940 there was already an accumulated deficit of 5,000,000 dwelling units, if we postulate a separate housing unit for each family.

What are some of the factors which brought about this prewar deficit or sub-standard condition? One is the tendency to continue to rent or to occupy a dwelling place beyond its useful life. Another is the end result of the 1929 depression. The country never caught up with itself to the point of launching a real home building program after 1929. In the large cities the growth of "distress" areas is a by-product of high land values and real estate taxation. Many distress areas in large cities represent land held at a value of $2.00 or more per square foot whereas housing, if built for rental to middle or low income groups, cannot afford to occupy land at more than one-fourth that value per square foot.

Low-cost housing cannot be tailor-made. It must apply materials and technics which vested interests (the most effective one of which is labor) tend to oppose. It also appears that there is not enough skilled (union) labor in the country today to build 1,000,000 housing units per year unless a very drastic change in thinking is brought about and until a substantial amount of prefabrication enters into the construction of the units themselves—as well as into kitchens, bathrooms and other components.

There are two Congressional plans to attack the housing deficiency. One is the Wyatt or Housing Administra-

tor's program—essentially a two-year project. The other, a long-range program, is outlined in the Wagner-Ellender-Taft bill.

Wyatt Housing Program

The Wyatt program (H.R. 4761) briefly provides for:

1. The promulgation of a policy to provide for the construction of 2,700,000 homes within two years. This amount to include permanent conventional houses, permanent prefabricated houses and temporary units.

2. Preference for veterans and their families in the rental or purchase of housing, but some provisions also for non-veteran hardship cases.

3. Production of conventional and new type materials to be expanded through: (a) the use of premium payments (subsidies) for increased production; (b) governmental guarantees of markets for materials manufacturers; (c) priorities and allocations of materials; (d) wage-price adjustments or price increases where necessary and not inflationary; (e) use of war plants and new facilities; (f) rapid tax amortization for plants which are newly built or converted to produce essential building materials; and (g) absorption by the government of undue risks in developmental work on new materials.

4. Attempted recruitment and training of 1,500,000 additional workers by the middle of 1947. This would more than triple the present labor force.

5. All deferrable and non-essential construction to be postponed for the balance of 1946 in order that needed materials and labor for veterans' homes can be released.

6. The government to make materials available and guarantee the market for the product, thus insuring rapid expansion of factory fabrication of materials and parts.

7. Priorities and allocations to be given to home builders for equipment and materials.

8. Federal co-operation to be given when necessary for the development of home sites.

9. The greater part of materials to be channelled into homes and rental housing selling for not more than $6,000 or renting for not more than $50, since that is the highest which the average veteran would be able to pay.

10. More effective price controls to be placed on building materials, ceilings to be put on new and on existing homes, and on building lots.

11. Insured mortgages to be provided on low-cost homes up to 90 per cent of their value, based on necessary current costs.

12. Community participation to parallel federal action to be taken through emergency housing committees in cities and towns; and, where necessary, state legislation to be advocated to aid in the veterans' housing program.

Wagner-Ellender-Taft Bill

The Wagner-Ellender-Taft bill (S. 1592) proposes:

1. A permanent national housing agency which will direct and supervise all the activities of the federal government relating to housing.

2. The establishment of research and related studies by the government in building materials, new design and construction, and every conceivable improvement for better, safer, cheaper and more healthful homes.

3. Disposition of war housing to be made in a way that will give veterans preference in renting dwellings in these projects. When it is in the public in-

terest, these war housing projects to be sold for low-rent dwellings.

4. Slum clearance through financial and technical aid by the National Housing Agency until all slums are abolished.

5. Help for people with moderate means so they can own their own homes; this to be done through the insurance of mortgage loans by the FHA up to 95 per cent of the appraised value of the house but not to exceed $5,000. The interest rate to be 4 per cent or less; and the mortgage to be good for a 32-year term. It also provides for the extension of the period of the mortgage if the home-owner is unable to pay because of unemployment or other conditions beyond his control. This would mean low down payments, low monthly payments and protection against foreclosure in times of need.

6. Stimulation of the building of low rental housing by allowing the FHA to insure mortgages up to 95 per cent of value at 3.5 per cent interest, and a 40-year term to co-operative housing projects, or housing projects instituted by federal, state or municipal corporations.

7. Public low-rental housing to be built for people in the lowest income brackets, who cannot afford to buy homes at any price and who cannot afford to pay more than $10 to $30 a month in rent. For these people, 500,000 units to be built over a 4-year period. These units to be publicly financed and built after a thorough study of local conditions and after determining that the projects are absolutely necessary and have the approval of the governing body of the locality.

8. Adequate rural and farm housing to be stimulated by allowing the Secretary of Agriculture to make 40-year, 3 per cent interest loans to build safe and sanitary dwellings for poor farmers, tenant farmers and farm laborers.

The Wagner-Ellender-Taft bill will not be discussed in detail here. Its scope is recorded so that water works executives will be able to understand the long-range implications of present Congressional thinking in the field of housing.

The premium or subsidy feature (item 3 of the Wyatt program) has been sharply debated in the Congress. As the Senate and House finally cleared (May 13, 1946) the bill for the President's signature, authority to pay premiums up to $400,000,000 to stimulate production was included.

The National Housing Administrator, or Expediter as he is sometimes called, is given authority to direct policies of both the Civilian Production Administration and the Office of Price Administration relating to production of housing materials. The Producers' Council has pointed out that productive capacity exists among going concerns to furnish all materials needed for the housing program, if price adjustments are made to the extent necessary to keep industry solvent. Today there is such a shortage of construction materials that the housing program cannot be carried on until the current limitations upon the production of construction materials are lessened.

Water Services for New Housing

It is highly difficult to estimate just how the housing program will create needs for water service and like community facilities. Row or group housing will require less materials for water mains and the like than would individual housing units. Housing construction in distress areas of large cities will require few main extensions but newly developed suburban areas will require

sizable extensions. Briefly, the Wyatt program might require the water works industry to extend its service during the next 2 years at 3 to 5 times the prewar annual rate. All depends on the sites chosen and the density of building.

The end of the war found the water works industry with an accumulation of deferred maintenance about equal to one full year's work. At no time since V-J day has the industry been able to replenish its depleted inventories nor has it been able to employ manpower to do the repair work it needs to do. Its postwar construction program has been stymied by lack of materials, uncertain prices and inefficient labor.

Understanding that the water works industry's part in any national housing program is one of the keys to its success, the A.W.W.A. staff has, since April 1, reviewed with the managers of the water systems in cities over 10,000 population the size of their inventories of water mains and related materials. These cities represent 75 per cent of the buying power of the industry. Today they stand unable to carry on the postwar construction program they had planned; unable to catch up on the maintenance work they patriotically withheld during the war; and apprehensive that the Congress will authorize the National Housing Program without clearing the way for price adjustments which will permit manufacturers to produce the things they need. How serious the problem is will be shown by the following condensed tabulation of nine classes of materials used in water distribution—the type of material the industry cannot do without and still serve new housing areas. The first column shows the number of weeks' supply the industry carried in 1940; the second column the number of weeks' supply on hand April 1, 1946; and the third column the number of weeks' wait the manufacturers state will be necessary before the material on order can be produced and delivered.

	1	*2*	*3*
Pipe	28	9	16
Fittings	55	10	14
Valves	26	10	14
Hydrants	23	11	15
Valve boxes	23	8.5	14
Curb boxes	23	7.5	15
Service line materials	30	9	16
Service line fittings	47	9	17
Meters	15	10	15

There is but one expression that characterizes the situation. The water works industry is moving toward a complete tail-spin in its ability to carry on even its *normal* activity. Every executive in the water works industry wants his city to do its part in the housing program. But this industry cannot contribute its part to the national housing program until the conditions which limit production of its construction and maintenance materials are recognized by those in authority and then forthrightly cleared away. Whether this clearing be done by the premium or subsidy route or by a reorientation of the policies of the OPA does not need to be debated here. But through one mechanism or another, the problems which the manufacturers of water works materials tell us they are facing today must be adjusted. They, along with other industrial groups in the United States, find themselves unable to make the things we need because of: (1) inadequate adjustment of price ceilings, (2) insufficient labor and (3) low productivity of labor. The first of these limitations is the most serious. All are important.

The country stands today with the Wyatt program ready to get under

way. But the country as a whole and the Housing Administrator face a situation best epitomized in a statement made on Apr. 22, 1946, by Thomas S. Holden, President of the Dodge Corporation:

Government regulations, particularly administration of the Price Control Act, are cited as the chief bottleneck of production by producers of such materials and equipment as masonry products, wood, metal products, glass, roofing and siding, heat insulation, wallboard, floor and wall materials, paints and finishes, doors, windows, hardware, sanitary equipment, water supply and drainage, electrical distribution, air conditioning and heating.

The situation is such that unless current price adjustments are adequate to insure reasonable profit and unless the manpower situation is corrected and labor efficiency improved in the near future, industry will be unable to carry out the veterans' housing program and other essential construction on the scale expected or on a scale the industry has the potential capacity to achieve.

Coagulation With Ferric Sulfate

By J. B. Nickel

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Presented on Nov. 15, 1946, at the West Virginia Section Meeting, Wheeling, W.Va.

ALL water works operators are probably familiar with one form or another of iron coagulation. The aversion of most water works men toward iron coagulation is doubtfully founded and probably arises from difficulties encountered in coagulation with ferrous sulfate. Although this discussion is devoted to coagulation with ferric sulfate, a brief review of coagulation with other types of iron coagulants will clarify the inherent differences between coagulating with any ferrous salt and any ferric salt.

Ferrous Sulfate as a Coagulant

The most common form of iron coagulation, and by that is meant the one most familiar to all of us, is coagulation with ferrous sulfate and lime. This form of coagulation has been called, by many authorities, the most economical means of water coagulation. The author does not entirely agree with this statement, however, since many of the difficulties encountered with the actual coagulation raise the total cost to the point where initial economy is hardly a consideration.

Ferrous sulfate, itself, is water soluble and will remain in solution for a long time in any water near pH 7. In order to have any coagulating value whatsoever, the ferrous sulfate must be converted to a ferric salt. This is normally accomplished by raising the pH with lime and then adding the ferrous sulfate. The reaction result is the formation of ferric hydroxide, the same coagulating material obtained with almost any ferric salt. A certain portion of the ferrous sulfate, however, will be converted to ferric carbonate, which has absolutely no coagulating value. From this it can be readily seen that only a portion of the iron actually available in the ferrous sulfate is utilized in coagulation. Furthermore, if excess lime is added, an unbalanced water may be produced, and the sand grains on the filters may be seen to grow. If an insufficient amount of lime is used, some of the ferrous sulfate will remain in solution and will pass the filters still in solution. This will cause red water difficulties in the distribution system, as well as inefficiency in the actual coagulation process.

These difficulties alone are sufficient to rule against the use of ferrous sulfate and lime in most water works plants. Ferrous sulfate, moreover, has a tendency to cake and normally cannot be used in all types of dry feeders because of this tendency. If stored in large bulk hoppers, it will often cake in the hoppers and may even require the use of air hammers to be broken loose. The most common method of storing ferrous sulfate is, of course, in

water-proof bags, and most plants do use the material in that form.

Ferrous sulfate can also be used with chlorine. This treatment is normally known as chlorinated copperas treatment. The ferrous sulfate is first put into solution and then chlorine is added in a ratio of approximately one to seven. The chemical reaction is to form a mixture of ferric sulfate and ferric chloride. This is a very excellent coagulant and certainly will do a fine job of coagulation. The disadvantages of this type of treatment are: (1) the ferrous sulfate is still difficult to feed; (2) the chlorination of the copperas causes quite a bit of fuming, so that, unless the process is properly protected, corrosion of the surrounding apparatus often occurs; and (3) the feeding apparatus is rather expensive and must be carefully controlled at all times.

Coagulation With Ferric Chloride

Ferric chloride is not normally employed in water plants because of its physical characteristics. The anhydrous material is far too expensive to use. The liquid material, although a cheap coagulant if the plant is located near a source of manufacture, requires rather expensive equipment for handling, for all unloading equipment must be rubber-lined, rubber-lined storage tanks must be provided and all feed lines must be rubber-lined.

Coagulation With Ferric Sulfate

Ferric sulfate has been long recognized by the general water works industry as an efficient coagulant but its general use was not adopted because of the very high price of the chemical. Until a relatively few years ago, in fact during the last decade, ferric sulfate was considered too expensive for normal use in water treatment plants. At that time, however, two manufacturers started making this chemical as a byproduct and the price now approaches that of alum. With the rather high cost of securing this chemical eliminated, therefore, its use began to grow rapidly in water and sewage plants throughout the United States. Unfortunately for the water works industry as a whole, however, the war has caused a very rapid expansion of its use. In the first place, ferric sulfate is used in the pickling of stainless steels and brass, in the manufacture of synthetic rubber, certain types of insulating boards and foam fire extinguishers, as well as in many other industries. All these industrial uses have claimed a large percentage of the total production of ferric sulfate during the war period. Furthermore, there are certain processes in the manufacture of powder that the presence of even the slightest trace of alum would disrupt; therefore, some coagulant other than alum had to be used. In most instances, these plants are now using ferric sulfate. For example, the atomic bomb plant at Hanford, Wash., has been using well over 500 tons a month of ferric sulfate for almost 2 years. All these government uses have forced the virtual withdrawal of both manufacturers from the municipal water works field and it is only very recently that any material has been available for new water works contracts. Were it not for these facts, there would have been a much broader use of ferric sulfate by now.

Ferric sulfate is not difficult to use but its use is different from that of alum and certain considerations must be made. In the first place, ferric sulfate is by no means as soluble as alum and therefore requires the use of differ-

ent types of dissolving equipment. Ferric sulfate, peculiarly enough, is more soluble in a small volume of water than in a large, because a more acid solution is rendered and because the heat of solution which is contained by ferric sulfate is not dispersed, with the result that a warmer water is obtained in the dissolving pot. Under normal conditions the proper water ratio is three parts to one part of ferric sulfate by weight. The ferric sulfate is first fed into a dissolving pot and water is added in the proper ratio. The material must then be violently agitated for a period of about 30 minutes before it goes into solution. Although this may sound rather complicated, further consideration will show that it is a relatively simple process to put the material into solution. The dissolving pot, for example, is not as large as it might sound. In the case of a water plant treating 12 mgd. of water with a maximum dosage of 81 ppm., usually a 20-minute retention period in the mixing pot is sufficient and a two to one water ratio is sufficient. Under such conditions, a 20-gal. crock would be a sufficiently large solution pot. A larger pot could, of course, be used without difficulty, if it should be desired.

The metering is relatively simple. A rotometer is probably the most common metering device for this purpose. Such a rotometer should read directly in pounds of water per hour, and should be so selected for size that the rotor rides about half way in the tube for normal operating conditions. The Omega Machine Company has made an Archimedes wheel as a measuring device for water on such feeders and a very simple homemade device can be utilized, whereby the water is fed into a constant level box, the overflow going to the dissolving pot outlet, and the water to the dissolving pot is controlled by a pinch cock.

The dissolved material from the solution pot is very strong and should be further diluted before going to the raw water. In fact, a 2 per cent solution has been found to be most satisfactory whether using alum, ferric sulfate or any other coagulant. Of course, this 2 per cent solution need not be accurately maintained and need be only approximated. It seems that any stronger solution will have a tendency to react with only a small portion of the raw water and thus fail to give a uniform coagulation of the entire mass of water.

Agitation of the dissolving pot is best secured by a small size mixer, probably a $\frac{1}{3}$-hp. portable mixer of the "Lightin'" type. It normally costs from $75 to $85. It will cost about $100 per average small feeder to install the proper dissolving equipment.

It is interesting to note that most plants have resorted to this type of dissolving equipment while they are still using alum. They have found that this type of dissolving equipment has several advantages even when used with alum. In the first place a true solution of alum can be maintained and thus all the alum that is fed is utilized. In many studies it has been found that much of the alum going into the raw water was undissolved. A sizeable portion of this material settled out into the sludge and never did properly react with the water. Still other material was carried beyond the mixing basin before becoming properly dissolved and thus carried free alum through the filters. This not only wastes alum but is not a situation to be desired in any plant. This change in method of dissolving alum is par-

ticularly noticeable during the cold weather. Many of the cold weather problems of plants using this solution have been eliminated. It is also interesting to note that the new Fall Creek plant at Indianapolis, Ind., built only a few years ago, employs large stainless steel dissolving pots, agitators and rotometers, for controlled alum solutions, plus controlled water temperature for feeding to the alum, thus assuring a complete solution of a known strength at all times.

The blades and shaft of the agitators must be of some acid-resisting material. Probably the most common is 18–8 stainless steel, which is strong and at the same time has excellent wearing qualities. Wooden paddles and shafts or wooden shafts and porcelain impellers can be equally well used but are not quite as long-lived as stainless steel.

The best material for the dissolving pot is probably lead; however, other materials can be used. Stainless steel is very good but it is too expensive for the average plant. Rubber-lined steel tanks are excellent but if the temperature in the pot should arise above 140° F., the rubber lining is damaged and the pot may fail. For this reason, it is not normally considered the best practice to used a rubber-lined dissolving tank. Lead-lined dissolving pots are satisfactory but lead lining is so thin that the abrasion from the insoluble particles of ferric sulfate may cause it to wear through rather rapidly, thus allowing the material to attack the iron or steel of the main dissolving pot and thus cause leaks. Crockery and Duriron are both very satisfactory but are subject to breakage by impact.

The lines from the dissolving pots to the point of application must also be given consideration. These lines may be of any acid-resistant material. The author prefers a rubber line, as it is easy to clean out and cheap to install. Rubber-lined steel lines are used in a number of plants and are very satisfactory. Lead pipe can be used very satisfactorily, particularly if it is protected from damage from impact.

Equipment for handling ferric sulfate up to the point of solution is exactly the same as that for handling alum. The material is no more corrosive than alum in the dry state. Thus, any standard dry feeder is perfectly satisfactory for the material, and it will store in bulk hoppers, bags, or other receptacles that are used for storing alum. It does not arch in the feeders and will store over long periods of time without lumping.

Ferric sulfate is somewhat more active chemically than alum and changes into an hydroxide more rapidly than alum. This means that the mixing characteristics of the plant should receive additional attention if ferric sulfate is to be used. The coagulants should be added at the point of maximum agitation. The quick mix is very important if good coagulation is to be obtained. A hydraulic jump probably is the most rapid and complete pre-mix but there are plenty of mechanical pre-mixers that give excellent results. The object of the pre-mixers is primarily to distribute all the chemicals throughout the main body of raw water before they have sufficient time to react with the raw water. This means that a violent mix is to be preferred, although any mix that works satisfactorily for alum should work satisfactorily for ferric sulfate. The coagulation or slow mix should normally be a little bit longer than that employed for alum. Alum starts to form its floc more slowly than ferric sulfate. The floc

then forms very rapidly and additional mixing beyond that point does little or no good. With ferric sulfate, the floc starts to form immediately after the introduction of the chemical in the water and continues at a rather slow and uniform rate of development for approximately 40 minutes before it starts to level off. This time will, of course, depend on water characteristics, temperature and other variables, but the 40 minutes can be considered the general rule. Ferric sulfate gives good results in many plants employing much shorter mixing or coagulating periods but it is believed that these plants are not operating at their maximum efficiency and even greater savings would be possible if they had longer mixing periods.

With this information on the method of feeding ferric sulfate it might be well to consider some of the characteristic reactions within the plant. Ferric sulfate is far less susceptible to turbidity changes than is alum. By this is meant that a change of turbidity that would require a change of dosage for alum coagulation may require no change of dosage with ferric sulfate. For instance, there is one plant on Lake Michigan using ferric sulfate regularly whose machines are set for a specific dose at all times. Variations in the turbidity of Lake Michigan water, although relatively few, are noticeable with alum coagulation but are not at all noticeable with the ferric sulfate coagulation. There is one midwestern plant that is subject to rather high flash turbidities, but they do not cause any particular trouble. True, the dosage should be increased for higher turbidities as a safety measure, but so long as just a small excess dosage is being used, a considerable change in turbidity can occur and good coagulation can be maintained throughout this period. This fact is quite helpful in plants where highly trained operators are not available at all times.

Ferric sulfate contains considerably more iron than alum contains aluminum and is, therefore, generally considered a stronger coagulant and smaller dosages can normally be used. In some plants, we find that 30 to 40 per cent less ferric sulfate can be used than alum. This is not true in all water plants, however, and cannot be taken as an absolute rule. It should be borne in mind that both coagulants have their place in the water works field and no absolute positive rule regarding their comparative performance can be established.

Ferric sulfate is particularly advantageous in water softening plants. It is not sensitive to changes in pH as is the case with alum. Alum is probably a little more efficient than ferric sulfate in coagulation at or near a neutral pH. From a pH of approximately 7.8 and up or pH of 6.4 and down, ferric sulfate will be found more efficient.

If lime or other pH control measures are used in ferric sulfate coagulation, it is generally considered best to apply the pH control ahead of the coagulant. Therefore, in a straight coagulation plant employing pH control for corrosion control in the distribution system, the lime should first be added to the water and then the ferric sulfate. This is an advantage as smaller dosages of lime are thus employed and less lime is carried on to the filters to clog them. Ferric sulfate is also very responsive to high-rate chlorination. It is generally found that high-rate chlorination very definitely improves the coagulating ability of ferric sulfate and so, if this type of treatment is used,

the water should be high-rated ahead of the coagulant if at all possible.

Ferric sulfate may or may not be the answer to the problem of color reduction. If high-rate chlorination is used for the color control, ferric sulfate will undoubtedly be a distinct advantage; however, if coagulation is done at slightly below 7.0 pH and if color is controlled by coagulation with alum, in most instances the alum will be found to be the cheapest coagulant to use. On the other hand, if it is necessary to reduce the pH below 6.3 or 6.4 in order to remove the color by alum coagulation, ferric sulfate may again prove to be the most economical coagulant.

For taste and odor control by coagulation, ferric sulfate is generally very effective. Many tastes can be removed by coagulation provided that they are not first fixed by a definite change in pH. This permits the addition of lime slightly ahead of the coagulant, thus maintaining the raw water pH throughout the coagulating process. If this can be done, many tastes can be removed by coagulation, tastes which are fixed if alum is used without lime and the coagulating pH lowered.

If iron is present in the raw water in any substantial quantity, it will normally react with the alum and interfere with coagulation. This same iron in conjunction with a ferric coagulant, however, will actually prove an aid to coagulation and dosages can be reduced to a minimum.

Conclusion

Although ferric sulfate requires some additional control in feeding, this is not serious and can be easily accomplished. In fact, if alum is to render its greatest efficiency, it should be fed in the same manner. There is no universal coagulant to date. Every operator should try the various coagulants to determine for himself just what coagulant is best suited for his plant's particular needs.

Recovering Well Capacity With Chlorine

By W. E. Huston

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Presented on Oct. 30, 1945, at the Illinois Section Meeting, Chicago, Ill.

IN 1935, two gravel-packed screen wells were constructed for the University of Illinois by a drilling contractor at a cost of about $25,000. At first successful, the flow from the wells, which were known as No. 10 and No. 11, declined rapidly. In March 1940, Well No. 10 was delivering approximately 25 per cent, and Well No. 11 approximately 45 per cent of the original specific capacity.

Diminishing well capacity is not uncommon in this region, but output from these wells had fallen off so greatly that the university supply was threatened. In 1940, as described by White (1), Well No. 10 was treated with acid. Since both calcium and magnesium bicarbonate were found in the well water, it was believed that calcium carbonate deposits might be encrusting the screen. An unsatisfactory increase in capacity, from 24.5 to 38 gpm., made this explanation seem inadequate, however, and it was decided to treat with chlorine as well.

Chlorine treatment raised the capacity from 38 to 50 gpm. per foot of drawdown. This was considered satisfactory even though the increase was somewhat less than that reported by Brown at Eau Claire, Wis. (2). The result seemed to indicate obstruction by an organic growth rather than calcium carbonate, and so the chlorine treatment was used before the acid in Well No. 11.

In Well No. 10, 52 per cent of the gain in specific capacity had been obtained by use of the acid; in Well No. 11, which received the chlorine before the acid treatment, 80 per cent of the gain in capacity was obtained by the chlorine. Figures 1 and 2 portray briefly the original and subsequent treatments and their results.

In 1941, the decline in flow from Well No. 10 was again critical, while flow from Well No. 11 had receded but slightly. The decline in both wells was serious in 1942, but no treatment was undertaken because of a wartime shortage in the chlorine supply.

In 1943, the pumps in both wells were breaking suction. Treatment with chlorine produced better results in Well No. 11 than in Well No. 10. This may have been due to differences in the construction of the wells. The 55 ft. of shutter screen in Well No. 10 is never totally submerged, while the 25 ft. of screen in Well No. 11 is submerged when the pump is idle. In the author's opinion, the results obtained in 1943 reflect the difference in the treatment of the wells in 1940, when acid was applied prior to chlorine in Well No. 10 and chlorine prior to acid in Well No. 11.

Chlorine and acid were applied in both wells in 1944, and experience seems to indicate that it is possible to overtreat with both. On starting the pump at Well No. 11, after applying

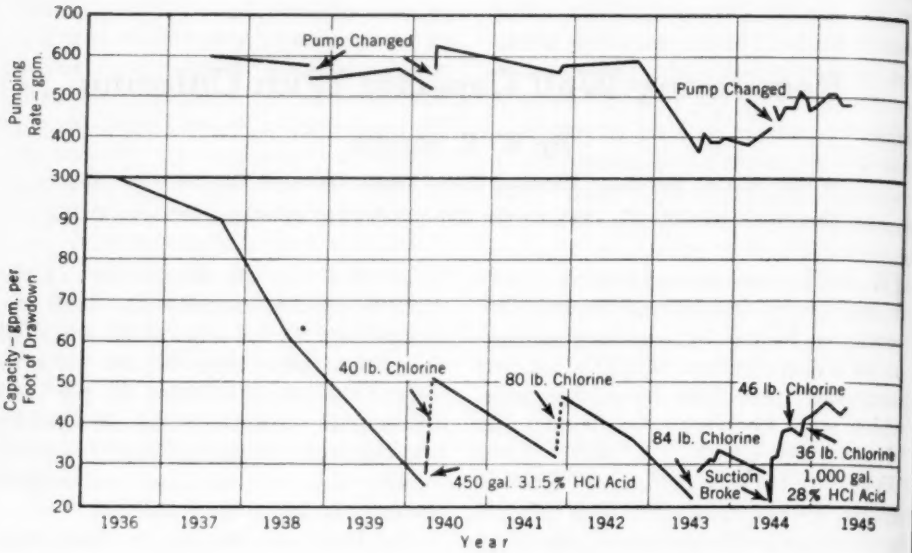

FIG. 1. Recovery of Capacity of Well No. 10

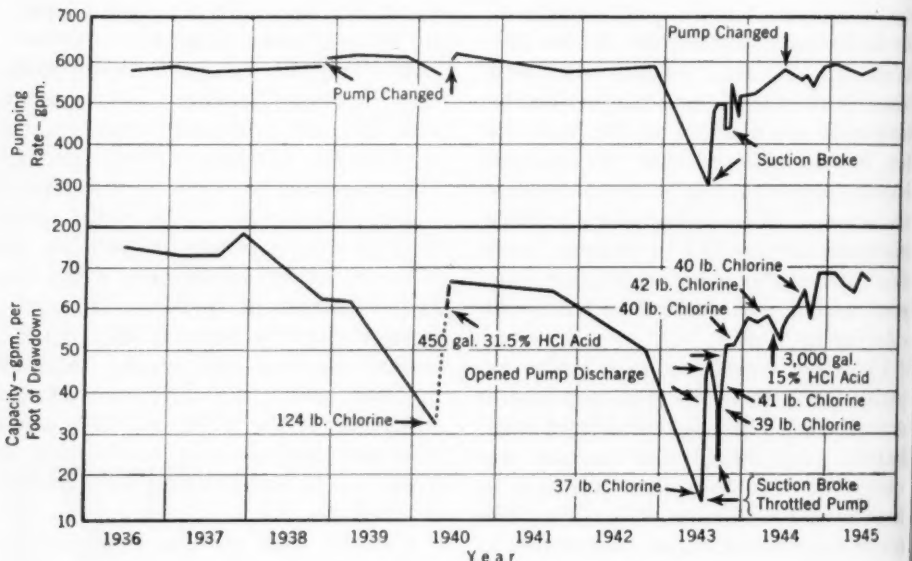

FIG. 2. Recovery of Capacity of Well No. 11

acid with the pump in place, no water at all was obtained, but, after starting and stopping the pump at short intervals for several hours, the condition improved. Two months later, the flow from the well was greater than it had been before the acid was applied.

A study of Figs. 1 and 2 indicates that the specific capacity of a well is not a straight-line function, but varies with the rate of pumping.

Some of the minor fluctuations shown may have been caused by variations in ground water levels or interference from other wells at the time the measurements were made.

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DISCUSSION—*T. E. Larson*

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The data presented in the author's paper are highly commendable because the condition of the wells before and after treatment is completely described. Altogether too often, the results of a well rehabilitation are expressed as an increase of production from one level to another, with no regard for the pumping rate. The obvious fact that the pump did not break suction after treatment may be mentioned, but even this does not indicate that the well had been improved unless it has also been noted that the pump did not break suction at the lower level. Otherwise, such data may be interpreted to indicate that the treatment or removal and drying of the pump had cleaned an iron deposit within the pump. Pump efficiency could be increased in this manner and production improved without any real change in the capacity of the well.

Actually, the improvement of the well described is better than was indicated, since the non-pumping water level had receded from 112 ft. in 1935 to 130 ft. in 1945. When Well No. 10 was pumping at a rate of 500 gpm. in 1935, water entered the well through about 41 ft. of screen. After rehabilitation in 1945, water entered through about 18 ft. of screen, or a reduction of slot area of 53 per cent. In other words, the loss in static level alone accounts for the subsequent reduction in slot area on pumping, and therefore the original specific capacity cannot be recovered. The data therefore roughly show complete return to the original capacity of the well.

This recession in the non-pumping water level, which precluded a return to the original specific capacity, may be a factor worth considering when rehabilitation is considered for other wells.

It should also be noted that the treatment described by Huston consisted of acid as well as chlorine and *not* treatment with an alkaline compound, such as sodium hypochlorite or calcium hypochlorite. The treatment involved the following reaction:

$$Cl_2 + H_2O \rightarrow HClO + HCl,$$

which produced an HCl acidity of about 0.5 per cent within the well bore when 40 lb. of chlorine were used.

Chlorine treatment and acidizing are useful and relatively inexpensive means of improving existing well and pump capacities, whether they are effective by cleaning the well screen and the surrounding formation, by improving the pump efficiency or even by cleaning the recording meter. The cost is often less than the cost of pulling the pump, and the period of outage is also likely to be shorter. Such treatment, however, cannot be expected to be a cure-all, and, as pointed out by Millis (1), the treatment should not be used without first determining the trouble to be remedied.

Chemical treatment cannot be expected to improve production if the condition is caused by a hole in the column pipe or pump bowl. Thorough production tests should be made both before and after the treatment to determine whether the treatment was successful in application or if misleading data were obtained. With such data available, it may then become economically advisable to treat at more frequent intervals rather than to gamble on the success of heavy treatment only after the condition of the well or pump has become so bad that emergency treatment is necessary.

It should be considered that a 10-ft. rise in pumping level is worth about 60¢ to 75¢ per mil.gal. pumped. Also, to use Mr. Howson's estimates (2), if cleaning the pump increases the efficiency by 10 per cent, this is worth approximately 80¢ per 24-hour day, at a power rate of 1¢ per kwhr., for every mil.gal. raised 100 ft.

Here again it is imperative that periodic factual data should be recorded in order that efficient and intelligent maintenance and rehabilitation may be accomplished.

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How to Prevent Breaks in Cast-Iron Pipe

By Thomas F. Wolfe

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Presented on Dec. 15, 1945, at the Four States Section Meeting, Baltimore, Md.

LIKE all materials of construction, cast-iron pipe must be properly designed, handled, installed and operated if it is to give good service. The design of modern cast-iron pipe is the result of numerous tests made for the purpose of determining the stresses under which the pipe must operate, as well as the physical characteristics of the material of which the pipe is made. As a result of these tests, it is possible to design a pipe that withstands normal internal pressure, water hammer, trench load and load due to surface traffic, as well as the usual handling hazards. If the conditions under which the pipe will operate are known, its design can be just as scientific as the design of any other engineering structure. These tests and methods of design are the result of the efforts of a committee of the American Standards Association, which has been engaged in the preparation of specifications for cast-iron pipe for a number of years.

Frequency of Breaks

Even though pipe is properly designed we know that breaks occasionally occur. Before considering the cause of these breaks and their remedy, let us for a moment consider the frequency of breaks. The amount of published data on which frequency of breaks can be determined is limited to the annual reports of a relatively small number of water works properties. These reports as a rule deal with the larger water works systems. In order to extend these data to smaller water works, a number of small and medium sized cities, ranging in population from 15,000 to 100,000, in the northern part of Illinois and the southern part of Wisconsin were selected as representing a fair sample of water works properties in this population range throughout the country. Each of the cities selected was visited and a record of its break experience was secured. This information is shown in Table 1.

It is to be noted that eleven of the properties surveyed indicated that no breaks were experienced in certain years. While there is a considerable variation between the poorest and best showing in Table 1, the over-all average of all of the properties indicates that less than one in every 60,000 lengths fails during any year. The average number of miles per break for larger cities is smaller than for the small and medium-sized ones covered by this survey. For example, in Chicago over a 5-year period there was an average of one break for 31½ miles of pipe per year; in St. Paul for a single year the average was one break per 29 miles of pipe. In Chicago the breaks in 6-in. pipe were 58 per cent of the total number of breaks, although the mileage was only 32.2 per cent of the

TABLE 1

Breaks in Water Mains in Eighteen Cities Under 100,000 Population in Illinois and Wisconsin

Location	Population	Miles in System	Length of Record, yr.	Number of Breaks During Best Year	Number of Breaks During Worst Year	Average Number of Breaks per 100 Miles of Pipe per Year	Average Number of Miles of Pipe per Break per Year
A	19,242	53	12	0	3	1.1	91
B	67,447	163	3	5	6	3.5	29
C	25,365	80	4	0	1	0.94	106
D	67,195	175	3	2	6	2.1	48
E	22,992	90	3	0	1	0.74	135
F	84,637	218	4	0	3	0.69	145
G	8,094	26	16	0	1	0.48	208
H	38,333	105	11	1	7	2.2	44
I	42,365	80	3	5	8	7.9	13
J	47,170	130	3	0	1	0.26	390
K	32,868	101	3	0	3	1.0	101
L	59,305	121	4	0	1	0.41	242
M	75,503	140	2	1	4	1.8	56
N	19,844	62	5	0	1	0.32	310
O	15,287	36	4	0	1	2.2	46
P	105,087	230	2	1	1	0.44	230
Q	65,389	130	4	0	5	1.7	59
R	48,765	124	6	1	2	1.1	93
						Average	131

total mileage. In the cities listed in Table 1, 57.2 per cent of the breaks occurred in 6-in. pipe. The age of the pipe covered by all of these data averages well over 50 years.

Alleged Causes of Breaks

In the course of the survey an attempt was made to determine from the operator of the property the cause for each break. Divided into broad classifications these causes are as follows:

1. Faulty construction or interference by other underground construction	58
2. Excessive pressure	11
3. Corrosion	10
4. Excessive load	5
5. Faulty pipe	5
6. No reason	37

The breaks listed under "No reason" are probably so classified because there was no evidence to indicate in which classification these breaks belong. Or, putting it another way, it was evident to the operator that the trouble was not caused by faulty pipe, corrosion, excessive pressure or excessive load. Consequently, it is fairly safe to assume that the breaks so classified should probably belong in the first heading, namely, faulty construction or other underground interference. Now let us examine causes for breaks mentioned above as well as others that may not be in this list and consider whether or not these influences by themselves can cause failure.

As a general rule excessive pressure can occur in distribution systems only when water hammer occurs. Water

hammer may result from a number of causes, such as the sudden shutting off of pumps connected directly to the distribution system (fire pumps, for example), the effect of "jumping" fire hydrants, loss of power at the pumping station, or the too rapid closing of valves. It is entirely possible that an instantaneous pressure rise of two or three times the normal working pressure may occur. In the design of cast-iron pipe, water hammer is taken into account and this fact, coupled with the fact that pipe is designed with high factors of safety both from the bursting and structural standpoints, practically eliminates pressure alone as a cause for failure in undamaged cast-iron pipe. In this connection, it is worthy of note that 6-in. class 150 cast-iron pipe will easily withstand over 2,200 lb. internal pressure before failure—a pressure much higher than is likely to occur even under the most severe conditions.

Another fairly prevalent idea regarding breaks, particularly in colder sections of the country, is that they are caused solely by the stresses set up by shrinkage due to temperature changes. Let us assume the worst possible condition with regard to temperature changes, namely, a pipe laid in the summertime when the temperature of the pipe may rise as high as 120°. Ordinarily, pipe is laid below the frost line and, consequently, its temperature will not drop below 32°. This gives a temperature range of 88°. In a pipe with its ends restrained, this would cause a stress in the wall of the pipe of about 7,000 pounds per square inch, or less than one-half the pressure required to cause failure in cast iron. Furthermore, before even this stress is developed, movement in the joints would materially reduce it. It is evident then that, even with extreme temperature ranges, shrinkage (unless it takes place in connection with other abnormal stresses) cannot cause failure.

Vibration is sometimes blamed for pipe failures. While it is true that excessive vibration may cause joint leaks both in lead and sulfur compound joints, and that these leaks may disturb the foundation of the pipe, the vibration itself is not harmful to the metal structure. We know that pipes connected to large reciprocating pumps, where vibration is excessive both because of mechanical vibration of the machine plus the pulsating pressures, do not fail. Vibration due to passing trains, streetcars, trucks, etc., does not equal in intensity the vibration of reciprocating pumps. Vibration by itself, therefore, cannot cause failure.

True Causes of Breaks

Three of the causes commonly ascribed to pipe failures have now been examined, and it has been demonstrated that each of these by itself cannot possibly cause failure, although it may be a contributing factor. Now let us consider what factors actually are the primary cause of breaks that do occur. They are:

1. Damage to pipe before installation
2. Damage to pipe by other underground construction work
3. Corrosion
4. The use of too large taps
5. Beam or ring failure due to:
   (a) Poor construction
   (b) Resting on rock or unyielding structures
   (c) Other underground construction causing disturbance of foundation of pipe, or causing other structures to rest on pipe.

Damage to Pipe

When failure is due to the installation of damaged pipes, the only remedy, obviously, is reasonably careful handling of pipe plus inspection of each pipe before installation.

Breaks caused by other underground construction operations, such as blasting or the use of power shovels and heavy construction equipment, can be avoided by inspecting such work in progress, warning the construction crew of the presence of underground pipe, and insisting on the exercise of reasonable care in the vicinity of such piping.

Corrosion

Failures due to corrosion are rare in most areas, but in some parts of the country they do occur. The remedy for this type of failure is to provide a non-corrosive environment for the pipe where experience has indicated or tests have proved that soil is corrosive. The use of sand, limestone screenings or marl for backfill around the pipe is desirable where pipe is laid in highly corrosive soils. This backfill should extend from approximately 6 in. below the pipe to 10 in. above. The use of backfill of this type serves three purposes:

1. It prevents actual contact of the corrosive soil with the pipe itself.
2. It provides a more uniform contact between the soil and the pipe.
3. It provides a comparatively porous area adjacent to the pipe, so that there is less opportunity for soil bacteria to attack the iron.

In certain types of soil, such as those found in marshes and highly alkaline areas, as well as some "made" soils, such as cinders, slag and coal mine wastes, it may be desirable to provide a special coating for the pipe. This may be a wrapped bituminous or cement mortar coating.

Too Large Taps

The use of too large taps obviously weakens the pipe structure, and good judgment requires that where large services must be connected to small diameter pipe it is advisable to use a fitting rather than a tap.

Beam and Ring Strain

The major cause of breaks in cast-iron pipe is beam action in pipes 8 in. and smaller in diameter and ring failures in pipes of larger diameters. A pipe properly laid and not disturbed after laying is not called upon to act as a beam and such a pipe cannot, therefore, fail as a beam. The backfill on pipe so laid stresses it as a ring in compression. Smaller diameter pipe will withstand as a ring many times the load that even an excessive depth of trench might transmit to the pipe. On the other hand a pipe not properly laid may act as a beam for any of several reasons. If blocks are used near the ends of the pipe and the backfill is not properly tamped the load placed on the pipe tends to bend it downward in the middle. If failure occurs with this type of loading, the breaks will be opened wider at the bottom than at the top. If the bottom of the trench is wavy, with deep and long bell holes, the pipe is supported in the middle and comparatively free at the ends. This pipe will bend downward at the ends and if failure occurs the break will be opened wider at the top that at the bottom. In either of these cases the pipe breaks straight across near the middle of a length. Breaks of these types are seldom found in sandy soils since the sand very easily flows around the pipe to form a good

TABLE 2

Safe Depth of Cover on Class B Pipe With Allowance for Water Hammer and Safety Factor of 2½

Size in.	Flat Bottom Trench Tamped Backfill ft.	Laid on Blocks Tamped Backfill ft.
8	13	8
10	11	8
12	10	8
14	9	7
16	8	6
18	8	6
20	8	5
24	8	5
30	7½	5
36	7½	5
42	7½	5
48	7½	5

foundation and in this manner prevents beam action.

With large pipes, beam failures do not occur, but a pipe laid in the fashion mentioned above may have concentrated loads placed on comparatively small areas. If these loads become excessive the pipe may fail as a ring, in which case the break is along the pipe and not straight across as in beam failure. The remedy for this type of failure is proper preparation of the trench bottom plus tamping of backfill. The use of trenching machines for bell hole digging very often results in excessively deep and long bell holes. These are undesirable particularly in clay soils. If bell holes are to be dug by trenching machines, care should be exercised so that the holes are properly located, are not larger than necessary, and the trench bottom between bell holes is level.

If a pipe is so laid that it rests on a rock, another pipe, a conduit or other unyielding object, the pipe is rigidly supported at this point and comparatively unsupported at other places along its length. This may cause beam failure in small pipes, and in larger pipes could easily cause failure as a ring. The remedy for this trouble is to excavate 6 in. below the bottom of the pipe where rock is found and then backfill with sand up to the pipe grade. With other underground structures care should be exercised so that pipe does not rest on them nor they on the pipe.

Table 2 gives the depth of fill that can be placed over various sizes of water mains and still maintain a customary safety factor of 2½. The table covers two methods of laying pipe: (1) a flat bottom trench with the backfill tamped around the pipe and (2) pipe laid on blocks with the backfill tamped.

Workmen can reduce the effect of these external forces and loads by proper installation. They should remember that pipes are designed to carry water, sewage, gas and other liquids and are not designed to serve as a beam or foundation for buildings. The University of Iowa has evaluated the various common methods of laying pipe, and these methods and values are shown in Fig. 1. These six views show the common methods of laying pipe and the bearing value of each for a 12-in. pipe. These bearing coefficients change for various sizes of pipe. The largest variation is in the smaller sizes of pipe.

The first view shows a pipe laid on blocks. This is the poorest way to lay underground pipe, especially for sizes under 12 in., because it produces a direct beam action, and long slender pipe are not suited to carry this type of load. Plumbers for years have used this method of laying pipe. If it is used, the inspector should insist on the contractor's tamping the backfill under and around the pipe. The two center

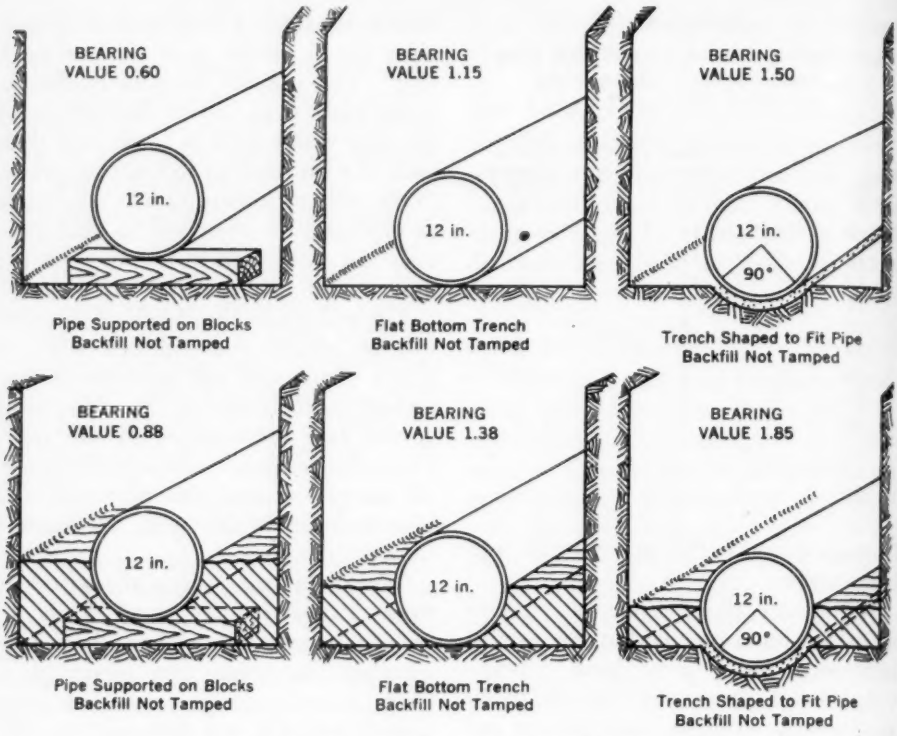


FIG. 1. Common Methods of Laying Pipe

views show the common method of laying water pipe, a flat bottom trench with the backfill either tamped or untamped. Tamping backfill up to the top of the pipe is worth the added expense. The two right-hand views show the sewer type of construction. This is not often used for water mains, but could be employed to advantage in special cases, such as near railroads, under deep fills and locations where there is a heavy load on the pipe.

Even if a pipe is properly laid, its foundation may be disturbed by other underground construction work, such as the installation of sewers, electric and telephone conduits, gas mains, services, etc. When this occurs, beam stress may develop. The remedy for this trouble is careful inspection of all underground work carried on in the vicinity of pipe lines, and requiring that if the pipe foundation is disturbed it must be replaced with properly tamped material.

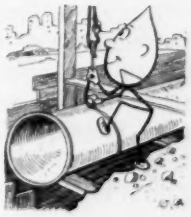
One might ask, if beam action is the principal cause of pipe failure, why do breaks occur with greater frequency in cold weather? The answer is that when the temperature of the water drops, pipes, already stressed by beam action, are called upon to take the additional stress of shrinkage. This, on a pipe that is already stressed just short of failure, may be sufficient to cause rupture.

Summary

In summing up, it is quite evident from the standpoint of both experience

and theory that the principal cause for the occasional break in cast-iron pipe is that the pipe is called upon to act as a beam, due either to faulty construction in the first place, or because of interference by other underground utilities at some later date. The remedy is better construction, that is, the proper preparation of the foundation for the pipe so that it rests for its entire length on undisturbed earth, or on a properly compacted bed. The remedy for interference by other underground construction is proper supervision of all underground construction carried on in the vicinity of underground piping. The comparatively rare break due to corrosion can be prevented by using sand backfill adjacent to pipe in mildly corrosive areas, or the use of special coatings in marshy places, or places where cinders or slag have been used for filling purposes. As streetcars are replaced with buses, the damage due to stray current electrolysis disappears; and in those places where streetcars still operate, co-operation between streetcar companies and the operators of underground utilities can prevent trouble from this source.

The precautions suggested are nothing more than good pipe laying practice. By observing them, breaks, with their accompanying annoyance and expense, can be an even rarer occurrence than they now are.



Preventing Sand and Sediment Deposits

By Oswald A. Gierlich

City Engr. & Water Supt., Manhattan Beach, Calif.

Presented on Oct. 23 and 25, 1945, at the California Section Regional Meetings, Los Angeles and Berkeley, Calif.

THE primary purpose of this discussion is to determine the most practical and economical method of preventing sand and sediment from wells from entering the transmission and distribution mains. The author does not herein propose to present a solution to this problem, as obviously it would require a comprehensive, detailed study by a technical agency, properly equipped to do the necessary research work in connection with a subject of such scope.

The two phases of the problems are: (1) the prevention as far as possible of sanding in the well proper and (2) the elimination or extraction of sediment and/or sand from the pump discharge line before they have entered the distribution system.

Water wells are a source of sand and silt which in turn cause many operating troubles, such as deposits in pipelines; the cutting out of working parts or plugging of meters; the scoring of valve seating, which causes leakage at customers' premises; and the plugging of sprinkler systems.

After drilling, most wells are thoroughly developed before being placed in service. Any well, however, when started will break some sand; some clear quickly, while others take a long time. Wells perforated in coarse gravel beds with large perforations will produce sand; many others cut in medium gravel and coarse sand with smaller perforations have been known to do so. Where fine sand beds are not perforated but coarse sand and gravels are, the water from the fine sand beds will run down outside of the casing to the beds that are perforated, washing clay from the intervening beds, causing the water to be turbid. The drawdown to the pumping level furnishes the differential head for flow outside the pipe between perforated and non-perforated beds.

Sometimes minor cave-ins cause the water to become turbid. When enough sand is pumped out of a particular stratum a cavity will be formed in it and the clay bed above it will sag down, causing a run of clay and sand, and in some cases even collapsing the casing—a potential danger which strikes day or night and usually when least expected. If the well is pumping directly into the mains a great deal of damage will have been done before its discovery. It will take many months to work it out of the system. In many wells that had been in use for a number of years, it was found that the amount of sand pumped was increasing. The condition was found to be induced by the plugging of perforations, which caused an increase in velocity of flow through the remainder of

the openings. After the perforations were reopened and the normal flow was re-established, the sand stopped running.

Gravel pack or envelope water wells, especially those using the most modern methods of drilling, presumably will eliminate, at least for a period of several years, a major portion of the sand; however, under certain conditions even such wells will, sooner or later, discharge a considerable quantity of sand.

To obtain economically the quantities of water required for public purposes, it is essential that water-bearing material be of a very porous character; however, those underground water basins removed some distance from the mountain ranges naturally contain less coarse materials than those basins adjacent thereto, it being a matter of necessity to perforate strata of material much finer than is required in the upper basins, with the result that a larger proportion of "sander" wells are developed in those areas.

Some wells are discharged through pressure sand and water separators or traps of both gravity and centrifugal type, some through gravity type concrete sand boxes into reservoirs, others into settling tanks and some directly into the system mains. We are all familiar with the practice of pumping the well water into a wier box or settling basin, which, after a short retention period, is again, through a centrifugal booster, pumped into a transmission main or the distribution system.

Settling basins and reservoirs, if used, are required to be removed from service and cleaned by manual labor. In many cases the sand is removed through a manhole in the roof. This method precludes the possibility of employing the far more economical method of pumping directly into the distribution system.

The saving in the latter method, especially where a utility has a number of widely separated wells, is illustrated by the hypothetical cases in the tabulation below:

Plant I

Deep well turbine to surface lift	$2,650
Settling tank	1,500
Centrifugal booster	1,800
Additional building and fittings	850
TOTAL ESTIMATED COST	$6,800

Plant II

Deep well turbine (pump into distribution mains)	$3,100
Pressure sand separator and fittings	1,700
TOTAL ESTIMATED COST	$4,800

The foregoing is based upon one well only being served by the pressure sand separator. At a small additional cost, however, a sand separator of capacity sufficient to serve two or more wells may be installed with a saving of perhaps $2,000 for each well served.

The author recently drilled two new wells 1,000 ft. apart which are both pumped through one vertical steel tank, pressure-type centrifugal-action sand separator, which removes all sand retained on a 150-mesh under a working pressure of 75 psi.

The velocity is 0.007 fps. when pumping 1,200 gpm. It is proposed that subsequently a third well be pumped through the tank, increasing the velocity to approximately 0.01 fps., with an estimated capacity of 1,700–1,800 gpm.

When consideration is given to both first cost and operating expense, the vertical steel tank, pressure-type centrifugal-action sand and water separa-

tor has proven to be the safest and least expensive. It is placed in the well discharge line, where it thoroughly removes from the water sand and silt which is free of colloidal matter. The centrifugal force removes sand and the retention period is greatly reduced over that required in gravity types. Working under pressure, it can be cleaned while in operation by opening a sand blow-off valve. It has great salvage value in that it can be moved to a new well if the old one is abandoned. It can be placed on wells isolated from storage tanks, which are pumped directly in the system mains.

Meter Reading, Billing and Commercial Practices Under Wartime Conditions

By K. F. Hoefle

Supt., City Water Works, Dallas, Tex.

Presented on Oct. 16, 1945, at the Southwest Section Meeting, Shreveport, La.

THE impact of war brought many difficulties to all public service utilities. The operation and maintenance difficulties that arose from the diversion of materials and skilled men to the armed forces and to war manufacturing are well known to all of us. They were overcome largely by expedients; equipment and facilities were operated to their limits, only the most urgent new construction was undertaken and much preventive maintenance was deferred.

Most of the activities of the commercial departments, however, could not be deferred. Not only did meter reading, accounting, billing and collections have to be kept current, but dwindling staffs, in many cases, had to handle bigger work loads. This paper will briefly describe how the Commercial Department of the Dallas City Water Works maintained satisfactory service under such conditions.

The operations first affected by the Selective Service Act after our entrance into the war were those of meter reading and inspection. Before the war, the department employed 23 men as meter readers and inspectors. Reading and billing were on a monthly basis and meter readers worked every day. When these men began to join the Armed Services, it became evident that replacements sufficient to meet the schedules could no longer be obtained. It was therefore decided to change the billing period from monthly to bi-monthly on all but industrial and commercial accounts. This change was put into effect in March 1943.

The immediate effect of this was to cut the reading load almost in half. The department was able, therefore, to suffer some reduction in personnel, and still take care of increased business. A secondary effect was produced in the office. Because of the spreading out of the major portion of the business over a two-month period it was possible to dispense with the service of one bill carrier, one bookkeeper, two tellers, one billing machine operator, one duplicate bill clerk, one telephone clerk and three senior clerks. Including meter readers, the total number of employees dispensed with was 23. It should be stated here that those persons were not discharged to fit the bi-monthly schedule. The department was simply fitting the work load to available persons, and persons displaced from these operations were used as replacements in other posts, or were retired as they reached retirement age.

Since bi-monthly billing was instituted, the business has continued to grow. In 1943, the division had 81 employees handling 77,169 accounts. In 1945, the department had 58 em-

ployees handling 82,640 accounts, 3,400 of which were billed every month and 79,240 every two months.

The response of customers to the new billing period was good. Because bi-monthly billing would conflict with customary business accounting procedure, commercial and industrial meters were left on the monthly reading and billing schedule. Such accounts are normally paid by mail and do not result in traffic through the office. Of the large number transferred to the bi-monthly schedule, a large proportion are paid at the tellers' windows. Bi-monthly billing has spread this traffic over a 2-month period, with the result that customers coming in to pay a bill can do so with less loss of time than formerly was the case. The results have been so satisfactory that it is planned to continue the bi-monthly billing.

Grills and Queues Removed

Incident to the hastening tempo of manufacturing for and supporting the war, people generally became a little more irritable, a little less inclined to put up with little delays, such as standing in queues or being shifted from one window to another. This became evident when migrations and shifting of defense workers brought into the office an increasing stream of applicants for transfer or for new accounts.

The lobby had the conventional arrangement of grills and windows, labeled "Cashier," "Applications," "Duplicate Bills," "Adjustments," "Refunds" and "Permits." A patron having business at one or more windows stood in line at each in succession. On crowded days this resulted in considerable lost time and not a little confusion. The time consumed by the patron seemed out of all proportion to the importance of the business at hand and the arrangement was decidedly not a good one from the standpoint of customer relations.

To effect an improvement, the lobby was rearranged and more space was provided for the patrons. All windows were dispensed with except cashiers' windows and they were confined to one side of the lobby. Comfortable seats were provided to accommodate patrons who had business other than the payment of bills at the tellers' windows. On one side of the lobby was placed a row of desks, each in charge of a competent clerk. Each clerk handles any business the patron has, whether it is an application for a new service, a discontinuance, refund of security deposit, or adjustment or complaint. The patron is seated across the desk from the clerk and his conversation with the clerk is private and unhurried, and all of his business is usually concluded at this place. It is a "one-stop" service (Fig. 1).

Plumbers likewise had to stand before a wicket to get permits for water services and sewer connections. That arrangement was particularly bad because it was not possible for the permit clerk to have in his cage all maps or records to which he had to refer before issuing a permit. He, therefore, had to leave his cage at times while one or more plumbers were lined up in front of the wicket.

In remodeling the office arrangement and procedure, this service was removed from the lobby to the Engineering Division office, and the permit clerks were seated at desks. Maps and necessary records are arranged for handy reference. The plumber is seated across the desk from the clerk; he is not left alone and his business is concluded with more dispatch. There

FIG. 1. Customers Applying for Water Service

FIG. 2. Plumber Applying for Service Connection Permit

are comfortable seats for any who have to wait (Fig. 2).

The reaction to these changes has been most favorable. The people like it. If they have to wait there is a comfortable seat, and they are comfortably seated while transacting their business. It gives them a few moments of relaxation and puts them in a better frame of mind. This practice will be retained as a permanent feature.

Accounts Transferred by Mail

Another innovation which has done much to improve customer relations, as well as lighten the office load, was in the matter of handling transfers of accounts from one address to another, and in handling applications for new services. It had been the policy to require applicants for service or transfer or discontinuance of service to come in person to the office and sign the application. This can now be done by telephone, or mail, if the customer desires. In the case of a new customer, a contract is mailed him for execution and returned with his security deposit. This service has been appreciated by busy people, and has been entirely satisfactory to the department.

All of these war-born innovations will be retained as permanent features. They have eliminated confusion, lessened traffic through the office, speeded up business and cut down costs. More important, perhaps, they have resulted in an improved atmosphere in the office, and have produced much pleasanter customer relations.

Meter Maintenance and Repair

By Harold L. Londo

Supt., Water Dept., Green Bay, Wis.

Presented on Nov. 14, 1945, at the Wisconsin Section Meeting, Milwaukee, Wis.

THE Green Bay, Wis., Water Department learned the value of meter maintenance the hard way. The city was completely metered by 1914, but no particular attention was paid to a regular maintenance program. Meters that were stuck, frozen or hit by hot water were brought in and repaired in a haphazard manner in a small dark room. This condition existed until 1936, when a new meter room, 21 ft. × 34 ft., was built. It was fully equipped with the latest in tools and testing equipment (see Figs. 1 and 2), and at last the problem could be attacked.

Meter Survey

The accounted-for water in 1936 was 64.54 per cent. It was decided to make a complete survey of the meters; this was started during 1937. The number of meters repaired each year was:

1937—1,166
1938—3,332
1939—2,670
1940—2,904

In all, during those four years, 10,072 meters were repaired at a total cost of $21,115.71.

The survey was started slowly so that any mistake made in the handling of meters and testing could be corrected before it had proceeded too far. Thus it was late into 1937 before it got into full swing.

The department had always used a ½-ton pick-up truck for its meter work, but since much of the survey work would be done in cold weather it was decided to purchase a panel truck.

At first, meters were reinstalled looking almost the same as when they had come out; then it was decided to spray-paint them before they were put back into service. A spray booth approved by the Industrial Commission was installed at considerable expense to the department, and repaired meters were placed back into service looking as well and recording as well as new ones.

It was decided (the assumption is still open to debate) that, to save a considerable amount of work in the office, the meters should be replaced in the houses from which they had been taken. This entailed the insertion of a nipple in the line until the original meter was returned, a lapse of generally five days to a week.

Two men were used in the field, the usual procedure being to remove meters and insert nipples in one group of houses in the morning, and replace meters that had been repaired and tested in another group of houses in the afternoon.

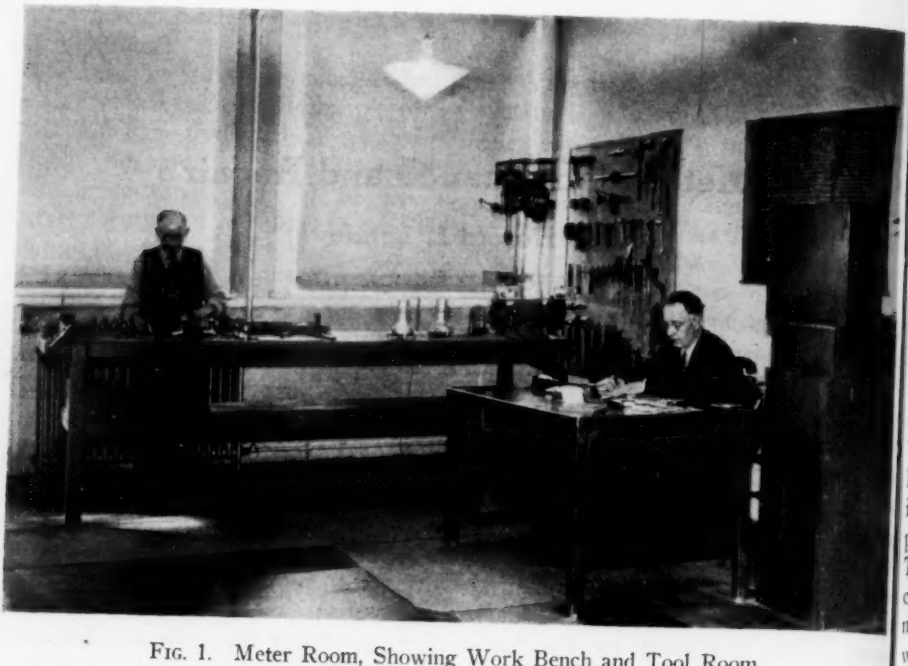


FIG. 1. Meter Room, Showing Work Bench and Tool Room

FIG. 2. Bins for Spare Parts and Service Fittings

When the meters reached the meter room, they were first tested on two flows, of 20 gpm. and 0.25 gpm., and the percentage of accuracy was marked on the test card. This card carries the following information: ledger number, the dates the meter was set and removed, the name and address of the tenant, and the kind, size and number of the meter, as well as the dates, readings and results of tests both before and after repair.

After the test for accuracy, the meters were taken apart and cleaned. The parts were put in an acid bath of Dearborn Chemical No. 134 and left in the bath from 3 to 15 minutes, depending on the strength of the acid. The parts were then put in separate compartments on the shelves. The meter body, cover and bottom bolts were taken to the spray booth and painted. The bottoms were painted black.

After the paint had dried, the meter was reassembled and new parts were added as needed. No attempt was made to repair old parts as time was an essential element in the survey. The new parts, their cost and also the labor cost, as well as the names of the persons who tested and repaired the meter, were then noted on the cards.

The meter was then tested again on the 20-gpm. and 0.25-gpm. flows, and, if satisfactory, the cover was screwed down and sealed. The meter was then placed in the bins for the outside crew to put back into service at its original location.

Large meters were tested in place or in some instances were brought into the meter room for complete overhaul and test. As the department had no tank large enough for direct volume testing, large meters were tested by comparison with a smaller meter of known accuracy.

Results of Survey

The following results were noted at the end of the meter survey:

In 1936, before the survey started, 64.54 per cent of the 1.064 mil.gal. pumped was accounted for, and $264,877.92 was received in revenue.

In 1940, the year the survey was completed, 81.44 per cent of the 1.066 mil.gal. pumped was accounted for, and $301,245.02 was received in revenue.

These figures show that almost the same amount of water was pumped the year before the survey started as was pumped the year it was completed, with the same rates in effect both years, but the revenue received by the department was $36,367.10 greater in the year the survey was completed. Thus the increased revenue in that one year more than paid for the cost of the entire survey.

It was decided to check meters every 5 years. At the end of this interval, a number of meters were taken out of service and tested. They were found satisfactory. It was then decided to check $\frac{5}{8}$-in. meters that had recorded 50,000 cu.ft. A number were brought in, tested, and were found satisfactory. Periodical tests will be continued on $\frac{5}{8}$-in. meters on the basis of both years of service and the amount of water recorded. From the results it will be determined when the meters should be brought in for examination.

Administrative Procedure

The Green Bay Water Department repairs all meters, and the cost, when the damage is caused by ordinary wear and tear, is borne by the utility.

Any meter damaged by frost, hot water or carelessness of the customer is repaired by the department, and the cost of the repair, plus $1.00 for removing and resetting, is charged to the customer or the owner of the premises.

If a customer demands that a test be made of his meter in addition to the periodic or installation test, he pays a test fee of $1.00 per inch of nominal size. If the meter should be found fast, in excess of 2 per cent, the payment will be refunded and the usual adjustment made in the past bills.

As of Nov. 1, 1945, the Green Bay Water Department had in service 11,047 meters, of five different makes. As soon as conditions warrant, two of these makes of meters will be taken out of service so that repair parts will only have to be stocked on the remaining three. In this way, maintenance should be simplified and efficiency, therefore, increased.

Distribution System Records

By Russell S. Banks

Local Mgr., Ohio Water Service Co., Marysville, Ohio

Presented on May 14, 1944, at the Ohio Section Meeting, Columbus, Ohio

IN order to function more efficiently in emergencies, one small water company devised a system of measurements and records for its valves and fire hydrants. Marysville, Ohio, with a population of 4,000, is probably a representative small water utility. It has 134 fire hydrants and a total of 81 gate valves, 4- to 12-in. size, 61 of which valve off sections of the distribution system.

Previous Maintenance Methods

There is but one regular service man who maintains the distribution system and reads meters. He has been with the company a good many years and is thoroughly familiar with the valves and the sections of the system they control. When a main breaks or other repair work is required, he secures temporary labor to assist in the repair. Fortunately, these temporary workers have been with the company on previous occasions and are more or less familiar with the work.

Little trouble was experienced in the repair of main breaks and other distribution troubles before the winter of 1936. A map of the distribution system was available, but there were no detailed records or data to help locate the valves in the system. The service man had always been very successful at locating them, and the only record was his memory.

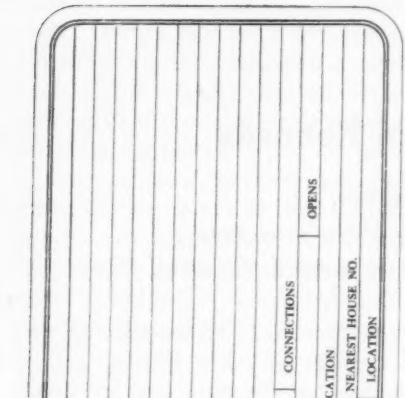
The winter of 1936 brought an unusual number of main breaks, and it was found that the snow and ice which covered the streets and valve boxes also covered up landmarks—and memory. Thus there was considerable difficulty in shutting off the water in the various sections. One bitter cold night will always be remembered: two main breaks occurred at the same time. All the valves had been closed in one section but the last, and this could not be located. The street was covered with about 2 in. of ice, and a group of men picked around in this ice from about 11 o'clock at night until daylight before finding the valve box. It was, by the way, just 8 or 10 ft. away from the spot where crippled memories just knew it had to be located.

Then and there it was resolved that another winter would not find the company without complete records on valve locations.

Establishment of Record System

A survey of the valves was made, and each located by two measurements. Bearings were taken from permanent landmarks, such as the curb or sidewalk line, as much as possible.

A visible-record loose leaf book was obtained to hold the information, and the pages were designed so that entries would begin at the bottom and read up. On the first or bottom line of the front



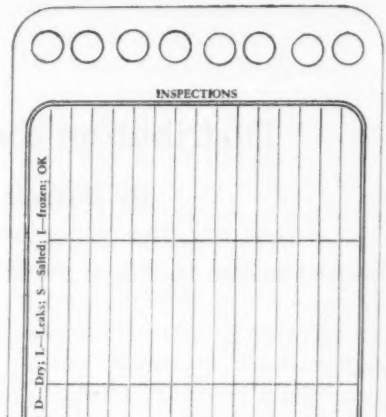
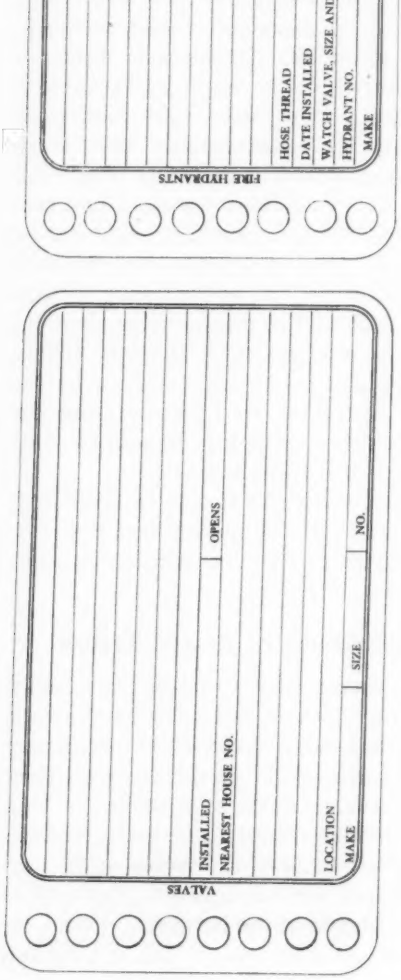


FIG. 2. Hydrant Information Form
Above, Front Side
Below, Reverse Side



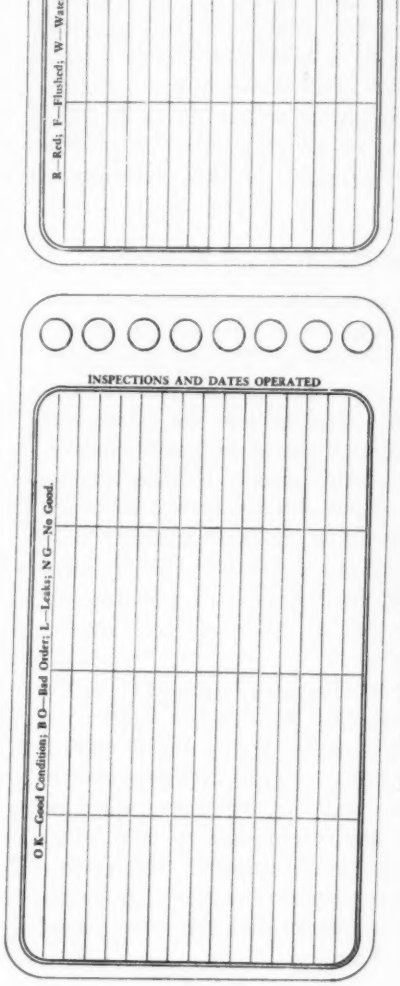


FIG. 1. Valve Information Form
Above, Front Side
Below, Reverse Side

side are shown the make, size and valve number; the next five lines are devoted to information locating the valve; then is listed the nearest house number; the date installed; and the direction of opening. In addition, there is sufficient blank space at the top for any additional remarks (Fig. 1).

The sheets are $5\frac{3}{4}$ in. by $3\frac{1}{8}$ in., and of course the amount of each that is visible when the book is opened will depend upon the number of cards arranged in a section in the binder. When using eight to sixteen in a section, the make, size, number and at least enough of the location to identify it are visible at a glance.

The back side of the form contains four columns which are used for noting inspection dates and findings. A code of abbreviations, printed along the top, is used to save space and simplify entries. Thus *OK* is used for "good condition," *BO* for "in bad order," *L* for "leaks" and *NG* for "no good."

A similar form was devised for fire hydrants, and printed on yellow paper to prevent confusion. Reading from bottom to top, as before, this form has space for information concerning make, location and number of the hydrant; size and location of the watch valve; date installed; direction of opening; hose thread; connections; and any pertinent remarks on maintenance work, or the like (Fig. 2).

The reverse side of this form is also used for inspection reports, using a different code of abbreviations: *R* for "red water," *F* for "flushed," *W* for "water" (does not drain), *D* for "dry," *L* for "leaks," *S* for "salted," *I* for "frozen" and *OK* again for "in good condition."

At the front of the binder is kept the index, which lists the valve numbers in blocks for the various districts. In the back is a map of the distribution system, cut into sheets and punched to fit the rings of the binder.

The record book is kept at the plant where it is instantly available to the distribution man or anyone else who may need it. A duplicate copy of the data on the valves is kept in a different location, as protection against loss or destruction of the original.

Although this may not be the last word in a record system for a small plant, it does have the memory system beaten a thousand times over. Too many water plants have gotten along in the past with distribution records contained only in the memories of faithful employees, and such a condition is neither healthy nor wise.

FIG. 2. Hydrant Information Form
Above, Front Side
Below, Reverse Side

FIG. 1. Valve Information Form
Above, Front Side
Below, Reverse Side

Accounting Practices for Canadian Municipalities

By S. Howard Gillett

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Presented on Apr. 10, 1946, at the Canadian Section Meeting, Niagara Falls, Ont., Can.

THE accounting department of a water works system which was created by the amalgamation of four municipalities and their associated systems—originally financed by the issue and sale of municipal debentures—faced some special problems.

The situation in Windsor is not typical of other water works systems in the Province of Ontario. In addition to the authority conferred by the Public Utilities Act, special powers were vested in the Utilities Commission by the City of Windsor (Amalgamation) Act. Brief reference to these powers indicates that they had a definite effect not only on the rate structure, but on accounting procedure as well.

Rates and Collections

The three existing systems, serving four municipalities prior to amalgamation, had distinctly different methods of collecting revenue. In two of them, all mains were laid as a general charge against the water system; in the other two, local improvement assessments were in effect. The cost of fire protection was paid by three councils but not by the fourth. The minimum charge on metered services differed in the various municipalities as did also the quantity of water provided on this basis. These factors had to be unified and a rate structure established to meet the needs of the new city. To complicate the picture, there was an extremely heavy debenture debt, and much vacant and improved property past which water mains had been laid had become city-owned due to nonpayment of taxes.

The Amalgamation Act permitted a rate not exceeding 11¢ per front foot being levied against all property abutting water mains, and a charge for fire protection not exceeding 3 mills against all rateable property, both vacant and improved. These have become part and parcel of the rate structure. At the present time the frontage rate is 6¢ per foot and the fire protection charge is 1½ mills. This basis of charging for fire protection, rather than the usual "hydrant rental," obviated all controversy between the council and the commission on either the annual rate per hydrant or the installation of additional hydrants from time to time. As assessment increases, the revenue from this source also increases. Hydrants are installed by the commission where and when needed without question. Since the outbreak of war, 145 have been installed where the need for them was apparent.

The water bill comprises four items: a stated number of feet of frontage at 6¢ per foot, the fire protection charge of 1½ mills, the minimum service charge based upon the size of the meter and excess water used, if any. For the ordinary domestic ⅝-in. meter the minimum service charge is $4.00 per year

for which 6,000 cu.ft. of water is furnished. The average domestic bill in Windsor is about 75¢ per month.

In recognition of the situation created by the amalgamation of the four systems which, having developed independently, bore little if any relation to each other, the commission was authorized to set up certain reserve funds for specific purposes. These could be for employees' and public liability reserves, the rehabilitation and replacement of works and undertakings under its control, and "other purposes." It will be seen that this gives the commission considerable latitude in the creation of reserves. Without these monies which had been set aside, the commission would have faced a very serious situation in meeting the demand for expansion placed on the water system by industrial and wartime growth during the past 5 years.

Accounting Records

As in any other business, the accounting records for a utility can be simple or elaborate. It is always desirable to keep a system of accounting as simple as possible, consistent with the necessity to provide the information required from time to time. A good accounting system is one which makes provision for recording financial data in such a manner that it can be utilized efficiently as a guide in directing the utility, and as a means of informing other commissions and municipalities of the utility's financial condition and operation methods. The system should be such that the auditing staff can determine readily whether all funds have been properly accounted for and all transactions handled in accordance with sound accounting principles. In 1938 the *Manual of Water Works Accounting* was published jointly by the American Water Works Association and the Municipal Finance Officers' Association with a view to standardizing water works accounting methods as nearly as possible.

For recording the accounting transactions of a water works system, a general ledger, accounts payable or disbursement record, cash receipts register and general journal are the controlling books required.

Accounts in the general ledger can be classified under four main divisions: assets, liabilities, revenues and expenditures. The classification of accounts may be as detailed or as comprehensive as those controlling the water works system may desire.

The accounts must, of necessity, reflect the type of plant which is being operated. It is obvious that a system involving deep well pumps as a source of supply would be quite different from one in which filtration was necessary.

The following accounts cover the requirements in Windsor:

Assets: Land, buildings, machinery, intake and well, distribution system or mains, hydrants, meters, gate wells and valves, tools, maps and records, automobiles and trucks, office furniture and fixtures, cash, bank accounts (capital and current), customers' accounts receivable, sundry accounts receivable, inventory of stores and supplies. There is nothing arbitrary about this; it is merely a question of fitting accounts to needs.

Liabilities: Debentures outstanding, reserve for depreciation, accounts payable, customers' deposits and surplus. The question of surpluses recalls the discussion of former years regarding their availability to the municipal council as a means of reducing the tax rate, and the clarification of the Public Utilities Act whereby a municipality cannot

now use water works' revenues for current municipal expenditures when there is an outstanding debt against the water works system.

Revenues: Revenues are classified according to the source from which they are received, to meet the need for statistical information for reports or other purposes. They appear under the following divisions: residential, commercial and industrial revenues; suburban sales wholesale; frontage charges on vacant property; street sprinkling, service and sundry repairs; and miscellaneous revenue.

Suburban sales wholesale is revenue from sale of water to outside municipalities based on the cost of water as determined from the previous year's operations, increased by 10 or 15 per cent, varying with different municipalities. This is rather low compared with almost any other rates throughout the province.

Frontage charges on vacant property are assessed annually against owners of vacant lots where there is a water main serving the property. The vacant property owned by the city pays the same rate as that which is privately owned. The charge for street sprinkling is a nominal amount paid annually by the city.

Service and sundry repairs are charges to customers for installing services, service repairs and repairs to damaged meters. Miscellaneous revenue includes, among others, revenue derived from discontinuing and restoring service. All new services are installed by the commission's staff at the expense of the owner. Repairs to house services between the curb stop and the meter are made by plumbers but are subject to inspection before backfilling.

Expenditures: The main divisions are filtering, pumping, distribution system expenses, administration, office expenses and fixed charges. Under these headings are accounts for the operation and maintenance of each of these divisions. Under filtering and pumping are salaries and wages; alum, coagulants and chlorination costs; power, fuel, machinery maintenance and other small expenditures. The distribution system expenses include maintenance and repair to mains and valves, service repairs, meter repairs, miscellaneous tools, truck expenses, trouble calls, etc. Administration and office expenses comprise office salaries, supplies and rent; meter reading; superannuation or pension payments; insurance; provision for bad debts; commissions paid collection agencies; audit fees; and probably a few miscellaneous items. Fixed charges would include debenture redemption, debenture interest and depreciation on equipment.

The only real difference between a private company and the municipal utility is in its capital structure. The company is financed by share capital which is usually permanent during the life of the company. The municipal utility is developed through the issuing and sale of debentures which are repayable over a stated period of years. Because of this difference in capital structure, the methods of handling depreciation are quite different. Bonds or debentures covering the construction or purchase of water works usually have a life of from 20 to 30 years. Plant value in municipal systems is frequently represented by the original cost less debentures redeemed. Insofar as buildings and water mains are concerned, the write-off over this period is generally sufficient, but the same cannot be said of such capital assets as

meters, trucks, tools and machinery, office equipment, maps and records, etc., if purchased by the issue of debentures. Every water works system should be empowered to provide a depreciation reserve covering these rapidly depreciating assets at a rate based on their actual, rather than their debenture, life.

Customers' Accounts

Customers' accounts records should conform to the size of the community served. The Windsor system is practically 100 per cent metered. At the close of 1945, there were 23,106 meters in operation. Of these, 22,591 were the ⅝-in. size, and the rest ranged from ¾ in. to 6 in. Residential and commercial customers are billed every 3 months; industrial customers, monthly. Customers' records may be kept on cards, or the stub system may be used. Billing machines and the card system are used by all larger utilities and are gradually being adopted by most systems. The records provided by a billing machine are concise and complete. All necessary records are obtained in one operation of the machine. The customer is rendered his account in detail, showing meter readings, various charges and gross and net amount; these readings and amounts are also posted to the customer's record card. By the same operation, a complete recapitulation of the billing is recorded and totaled for entry to the control ledger. Posting of payments of accounts to the customer's record card is also accomplished on a posting machine which gives daily totals of receipts for entry in the cash book and control ledger.

The aggregate of the balances on the individual cards must at all times agree with the controlling account in the general ledger, and a periodical test of this insures that all receipts are properly accounted for. Customers' cards with rulings for quarterly billing have a life of from 4 to 6 years. The recapitulation gives a most complete record of the billing. Such totals as minimum or service charges, excess water used, frontage charges, fire protection, total gross and net billing are all segregated, and the information is available for any desired purpose.

Other Records

Besides the ledgers and customers' billing and records, there are other necessary records. Work orders with progressive numbers are issued for all jobs regardless of the size. When the work is completed, the work order is returned with particulars of labor and materials to be charged to the proper account, or to any individual or organization for whom the work was done. Purchase orders are issued for needed materials, and requisition slips are made for supplies required from stores. With the taking of a physical inventory, a check is kept on stores and materials, which minimizes the possibility of leakage of materials from stores. The supplies and tools on all service trucks are checked monthly.

With income tax, unemployment insurance, war bond and other deductions to be made from employees' salaries and wages, it is essential that a suitable payroll system be kept from which the government can be furnished required information. Payrolls are made from employees' time sheets and records, as verified by the superintendents of the different departments. Filing the various returns now required by all governmental agencies is no small part of the accounting procedure.

Other essential records include service application forms, customers' de-

posit records, meter installation and removal slips, meter reading books, plumbers' permits, collection agencies' records and other forms to meet the needs of the individual system.

At the beginning of each year it is advisable to prepare a budget or estimate of anticipated revenue and expenditures for the ensuing year. This can readily be accomplished by reference to the previous year's operations and any anticipated changes, such as an increase or decrease in the number of customers, reduction of debenture debt payment or other factors which might affect revenue and expenditure. From these estimates, management can readily determine if an adjustment in rates to customers is desirable. The availability of information from the accounting records makes the preparation of the annual report a relatively simple procedure.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

STREAM POLLUTION CONTROL

Stream Pollution Problems of the Tennessee Valley. W. G. STROMQUIST. Paper Tr. J. TAPPI Sec. 186. **118** ('44). TVA, in cooperation with U.S.P.H.S. and health depts. of states concerned, has made survey of conditions in major tributaries of Tennessee R. and in 4 sections of Tennessee R. itself. Samples of water collected weekly for 8 to 12 mo. at points where sewage and trade waste waters dischgd. to rivers. Sewage and trade waste waters dischgd. to Tennessee R. basin had pop. equiv. of 560,000 and 1,300,000 respectively. More than half of over-all total load contributed by less than 20 factories making pulp, paper, and artificial silk. Estd. that since war load has increased and has now pop. equiv. of 2,300,000. Rivers of Tennessee R. basin seriously pold. only in certain sections. In '40, out of pop. of 871,000 served by public water supplies in Tennessee valley, 45% obtained water from pold. surface sources. Probable that this percentage will increase, as ground water supplies in some areas becoming inadequate. Artificial lakes in Tennessee R. basin used for boating, fishing and food. TVA has authorized further studies on conditions in rivers, with particular reference to effect of impounding, and has drawn up program for control of poln. Pulp, paper and paperboard industry has organized National Council for Stream Improvement with which TVA will cooperate.—*W.P.R.*

Waste Waters From Suction Gas Plants. H. J. BANDT. Gesundh.-Ing. (Ger.) **63:** 19 ('40). Considerable increase in number of gas engines used as sources of power for small and medium-sized indus. plants in Magdeburg dist. Dischg. into small streams of waste water from washing gas has led to odor nuisances and death of fish. Waste water contains phenols, H_2S, NH_4 salts and cyanides, all of which toxic to fish. Compn. of waste water varies according to type of fuel used to produce gas. Where danger may be caused to fish life, fuel, such as anthracite, which contains little N and S, should be used. Amt. of wash water used about 12 l./cu.m. of gas washed. According to author's experience, if brown coal and briquets not used, waste water may contain as much as 50 mg. of H_2S, 90 mg. of cyanide as KCN, 80 mg. of NH_4 salts, 3 mg. of phenols volatile in steam, as *m*-cresol, per l. This small amt. of phenol not likely to cause trouble even in small streams unless it comes into contact with Cl and forms chlorophenols, which, if present in water in concns. as little as 0.1 mg./l., may make fish unpalatable. NH_3 largely present as salts. NH_4CN quite as injurious as KCN. Most of H_2S escapes into air and part oxidized by D.O. in water. Cyanides easily oxidized in dil. alk. solns. and rendered harmless, but this does not occur as rapidly as commonly supposed, as shown by author's investigations of 3 recent cases of deaths of numbers of trout. Rate of flow in small streams often very great so that waste water carried considerable distance before H_2S and NH_4CN rendered harmless. In order to remove toxic substances from waste water before it is dischgd. to stream, it can be aerated or treated with hot exhaust gases from gas engines in Humboldt-Deutz plant for removal of odor. With aeration alone,

and to some extent with second process, H_2S driven off unchanged and must be dischgd. from tall chimney or burned. Aeration without acidification of waste water may not remove all cyanides and therefore use of Humboldt-Deutz plant preferable. In this, waste water sprayed downwards countercurrent to hot exhaust gases; H_2S oxidized by H_2SO_3 in exhaust gases and NH_4CN decompd. Usually amts. of SO_2 and CO_2 in exhaust gases sufficient to react completely with constituents of waste water. Too much H_2SO_3 should not be allowed to enter stream, as 0.5 mg./l. toxic to fish; it is, however, very easily oxidized and also reacts with Ca salts dissolved in river water. If exhaust gases very rich in SO_2 only part of them should be allowed to come into contact with waste water. Treated waste water should be dild. with cooling water from gas engines and dischgd. to stream. If amt. of exhaust gases available too small to react completely with toxic substances of waste water, latter should be subsequently treated with soln. of Fe salt to remove remaining H_2S and to form less toxic complex salts of Fe and $(CN)_2$. Pptn. of cyanide as Prussian blue not satisfactory in waste waters with low content of cyanide. Use of Cl to destroy cyanides unsuitable because of presence of phenols. Method of treating waste waters from gas plants must depend on local conditions. Author has used at small plant method in which waste water allowed to flow over meadowland where, before reaching stream, it had to pass through 2 banks of ashes; water reaching stream free from H_2S and cyanides.—*C.A.*

Treatment of Laundry Wastes. J. A. McCarthy. Annual Rpt., Mass. Dept. Pub. Health ('41); Sew. Wks. J. **15**: 580 ('43). High deg. of purif. attained when waste water from laundry treated on percolating filter; pH value of waste water 11.0. Effluent clear and contained little caustic alky. Content of grease reduced by filter from 267 to 35 ppm. Filter at first dosed at rate of 1.0 to 1.5 mgd./acre. When dosing rate increased suddenly to 10 mgd./acre filter became overloaded. When waste water from laundry treated with 393 ppm. of alum and allowed to settle, 89% of turbidity, 84% of grease and 74% of B.O.D. removed. Slightly better results obtained when 547 ppm. of ferric sulfate used instead of alum. Sludge produced with alum contained 41% fat and 74% volatile matter; that produced with ferric sulfate had similar compn. Both sludges dried readily and were not putrescible. Use of sulfuric acid, added before or with alum, or before ferric sulfate, reduced amt. of alum required by 70% and amt. of ferric sulfate required by 80–90%. Most economical results obtained with alum and acid when final pH value between 4.5 and 5.0. Cost of treatment with ferric sulfate and acid least when final pH value between 3.0 and 3.6. Most concd. sludge obtained with acid and ferric sulfate.—*W.P.R.*

Effect of Waste Water From Cellulose-Manufacturing Industries on Fish. H. Liebmann. Angew. Chem. (Ger.) **54**: 499 ('41); Wasser u. Abwasser. (Ger.) **40**: 61 ('42). Direct poisoning action observed only in concd. wastes or waste from sulfate cellulose plants. Indirect harm caused by reduction in O content, poisonous action of H_2S, and fungus growth (through further O consumption in decompn. of dead material). Waste should never be dischgd. into quiet water, and even in flowing water it creates zones poor in plant and animal life. No waste water from wood-sugar industry unless fermentation to alc. and production of fodder yeast undertaken. In latter cases $KMnO_4$ consumption may be as high as 20,000 mg./l. From standpoint of waste water, Bergius process to be preferred as HCl recovered. In Scholler process, where H_2SO_4 not recovered, more impurities in waste water.—*C.A.*

Trends in Handling Pulp and Paper Mill Wastes. H. W. Gehm. Sew. Wks. Eng. & Munic. Sanit. **16**: 501 ('45). Kraft mills segregating and lagooning concd. wastes; this method not always successful. Impounding of dild. wastes being tried with possible re-use of water. White water treated with alum and settled (this removes 90% suspended solids), sludge vacuum filtered and delivered to board mill for use. Full-scale installation of aeration system in stream to reduce B.O.D. and accelerate purif. of stream in operation. Development of by-product recovery from waste liquor in direction of obtaining lignin, vanillin, plastics and ethanol. Pulping processes employing magnesia, Na and NH_4 base liquors in which org. material constituents burned for steam production receiving increased attention. Also under development processes for evapn. and burning of Ca-base liquors. About $500,000 spent on research to develop treatment methods.—*C.A.*

Progress in the Treatment of Waste Waters in the Region of the Mulden-Wassergenossenschaft. KUNZE. Papier-Fabr. (Ger.) **5**: 164 ('43). Amt. of poln. of Mulde and its tributaries and methods adopted at pulp and paper mills for treating waste waters described. In '36 total amt. of settleable solids dischgd. to Zwickau Mulde and its tributaries between sources and Wilkau, above Zwickau, 850 cu. m. per day, of which 786 cu. m. dischgd. from pulp and paper mills. Twenty pulp and paper mills responsible for 697 cu. m. per day. Eleven of these 20 mills, which in '36 dischgd. waste waters contg. 545 cu. m. of settleable solids per day, in '41 dischgd. only 231 cu. m. of settleable solids per day. During period '36 to '41 each of these 11 mills reduced considerably amt. of sludge dischgd. per ton of product mfd.; in one case reduction from 3.6 to 0.1 cu. m. Most of large vol. of water used in mfr. of pulp and paper finally dischgd. as waste water; little evapd. and little remains in product. In number of processes much of water can be re-used after removal of solid matter in save-alls, settling tanks or filters. In region in which Mulden-Wassergenossenschaft operates several mills use VIB process for treatment of waste waters. This process, which has yielded good results, described; some of waste waters recirculated and some dischgd. to stream after sedimentation; settled sludge returned to hollanders. Theoretically, should be possible to re-use all waste water. Colloidal matter may be removed from waste waters by addn. of milk of lime or milk of lime and alum. Value of pH must be controlled; if it is desired to lower pH only slightly, tannic acid from decorticating drum may be used. Increasing use of wet process of decortication has made thorough treatment of waste waters necessary. When hot water used for decortication waste waters contain substances in soln. and must be given chem. or biol. treatment. Advantages of number of small save-alls as compared with fewer large save-alls discussed. Sveen process introduced by several mills and proved satisfactory. In this process Sveen lime added to assist coagulation of suspended matter in waste waters. Waste waters which are not seriously pold. should in general be kept separate from more pold. waste waters; they do not usually require treatment and can be re-used or dischgd. to stream. Screenings and sludge should be disposed of on land where they cannot be washed into stream.—*W.P.R.*

Progress in Methods of Slime Control. J. R. SANBORN. Paper Tr. J. TAPPI Sec. 243 **119** ('44). Development of chem. methods of treatment for controlling slime in paper mills discussed. Chlorine and chloramine found effective on certain kinds of bact. slime only, so treatment with 2 or more chems. adopted. Chems. used include copper sulfate, zinc hydrosulfite, hypochlorites, phenolic materials and compds. of mercury. Investigation of flora of slime in 340 pulp, paper and paperboard mills showed coliform bacteria present in 52.6% of mills, other non-spore-forming bacteria in 32.6%, spore-forming bacteria in 30.3%, fungi of mold type in 47.6% and yeast-like fungi in 41.8%. Types of micro-organisms in slime vary with type of mill, operating practices, seasons and condition of fresh water, pulp supplies and raw materials. Considerable variation in susceptibility or resistance of various groups of micro-organisms to usual methods of chem. treatment. One of most important factors in control of slime is efficient cleaning of pipes. Removal of masses of slime, in which living slime- or gum-producing organisms embedded, essential to permit penetration of disinfectant to living cell. Effs. of 130 chem. compds. for controlling most aggressive and resistant types of organisms found in mill slimes examd. Of total number of compds. tested 25 shown effective in controlling nearly all types of micro-organisms; these compds. included trichlorophenate fractions, metallic salts of chlorinated phenols, chlorinated isopropyl phenols, and various alkyl derivatives of halogenated phenols. In many cases even most resistant slime-producing types of micro-organisms elimd. by use of mixts. of chlorinated phenols.—*W.P.R.*

Sewage and Trade Wastes in Stream Sanitation. NORMAN J. HOWARD. Eng. Cont. Rec. **58**: 10: 86 (Oct. '45). General discussion of waste disposal in relation to natural purif. of water. Legislation enacted in both U.S. and Canada to prevent undue poln. but enforcement difficult, industries often claiming that burden so imposed would restrict mfg. Trend, however, is to place responsibility on industry concerned and constr. of major sewage disposal and treatment plants as postwar projects should render legislation more readily enforceable in regard to remaining sources of poln. Phenol rapidly destroyed by plankton and bacteria

and hence tastes and odors less prevalent in chlorinated water in summer when biol. activity at max. Indiscriminate dischg. of sewage into Great Lakes has resulted in changes in mineral content of water within 10 mi. of shore. In vicinity of Toronto, Cl^- content of L. Ontario water has increased from 7 to more than 16 ppm. since '11. Ammoniacal N also high at times. D.O. content, however, high and frequently reaches satn., despite heavy poln.—*R. E. Thompson.*

Industrial Waters of Canada. Interim Report No. 6. HARALD A. LEVERIN. Can. Bur. of Mines, Memorandum Series No. 85: 40 pp. (Jan. '44). Tabulations of anals. of 54 samples from surface sources and 104 from civic water supplies during '41–'43.—*R. E. Thompson.*

Water Supply and Sewerage as Factors in the Location of Industry. R. G. MURDOCH. Surveyor (Br.) **103**: 333 (July 14, '44). Availability of adequate water has frequently been deciding factor in choice of site for new factory. Industries requiring ample supplies are laundry, dairy, food canning, paper works, bleaching and dyeing and rayon mfg. Brewery or mineral water factory may take 100,000 gal. (Imp.) in 8 hr. Simplest way of disposing of trade effluents is to dischg. to public sewerage system. Owners of new trade premises can be compelled to fulfill certain requirements before waste accepted into public sewers. Notable exception is that laundries not required to obtain authority's permission. In some cases charges for sewer service vary between 1*d.* and 6*d.* per 1000 gal. (Imp.) according to strength. Local authority which asks no payment offers inducement in preference to one which does make charge.—*H. E. Babbitt.*

The Utilization of Municipal Waste Waters. D. MÖHLE. Städtereinigung (Ger.) **34**: 56 ('42). Nitrogen, potash and phosphates present in sewage can be used to replenish these constituents in soil; org. matter aids formation of humus, and water present useful in periods of drought or where soil pervious. Sewage purified by biol. agencies in soil. In Germany, sewage from 7,000,000 people used for agric. purposes. Distributed by irrigation or as artificial rain. Sewage also discharged into fish ponds; good results obtained with fish such as carp and tench which thrive when content of D.O. low. Water with surface area of about 1 ha. required for sewage of about 2000 persons and will produce yearly about 500 kg. of fish. Sewage sludge, digested and well dried, can be used as fertilizer. In Germany, sludge gas used extensively for heating and power to supplement gas supply of towns, and as fuel for automobiles. At Munich sewage works 10–15 tons of crude fat extracted annually from sewage and sold to soap factory, but as a rule impracticable to extract fatty material at sewage works. More economical to extract fat at source, for example at slaughterhouses, restaurants, etc. When munic. sewage contains large vols. of trade waste, necessary to ascertain whether wastes being treated sufficiently at source. If useful materials to be extracted, wastes should not be dild. unnecessarily. Thus, at slaughterhouses, fat retained in grease traps, dried blood mixed with bran or molasses for use as forage meal, and solid wastes, composted with street sweepings and lime, used as fertilizer. In milk industry lactose and lactic acid obtained from skimmed milk and whey. Waste pickling liquors treated for recovery of ferrous sulfate. Waste liquid from pickling with hydrochloric acid contains ferric chloride and is suitable raw material for prepn. of ferric oxide pigments. Copper can be recovered from waste copper liquors by "cementation" process or, where cheap elec. current available, by electrolysis. Waste waters from carbonization of coal injurious to river water. Contain phenols and cresols which, even at great dilns., affect taste of fish reared in river, and may cause tastes in water supplies after chlorination. Plants constructed for extraction of phenol by benzole in which 90% of phenol present removed. Sludge from washing coal can be used as fuel if dried and mixed with coke slack settled from coke-quenching water. Waste liquor from mfr. of potassium chloride contains magnesium salts, and if dischgd. to rivers, increases hardness and content of dissolved solids in water; magnesium can be removed as solid magnesium chloride from which metallic magnesium can be prepd. Waste waters from wool washing treated with sulfuric acid for removal of fat. Extracted raw fat can be converted into pure wool fat and residue can be used as fertilizer. Emulsified fats can be separated from waste water by centrifuging. Fertilizer contg. potash can be prepd. by evapg. exhausted fermenting soln. used in mfr. of pressed yeast. Waste liquors from mfr. of cellulose contain lignin

and have very polg. effect on rivers. Liquor can be used as source of alc., tannin compds. and pitch. Paper of inferior qual. produced from fibrous material recovered from waste waters from mfr. of paper.—*W.P.R.*

Treatment of Industrial Wastes. GEORGE E. SYMONS. Can. Engr.—Wtr. & Sew. **82**: 11: 42 (Nov. '44). Extended discussion of indus. waste poln. and remedies. Solution of problem should be important part of post-war planning. Huge vols. of water used in various industries shown in tabulation. Historically, diln. common method of disposal but with increased indus. development capac. of streams to serve in this way overtaxed. Resulting loss includes not only depreciation of water courses but also, in some instances, economic loss to industry through waste of valuable materials. Recovery measures, however, limited by potential markets for recovered byproducts. Distillery industry profited tremendously by waste recovery. Recent national surveys indicate that poln. abatement in U.S. will cost several hundred million dollars. Abatement programs should be considered first on drainage system or regional basis. In dealing with local problems, should be remembered that abatement is object, not persecution of industry, and relations with latter should be predicated on mutual co-operation. Final solution may involve complete elimn. of waste, pre-treatment before dischg. into sewers or treatment with munic. sewage. In latter case, industry should pay its share of cost. Charges now made in number of cities, and author and associates developed formula at Buffalo for detg. such charges. 18 refs.—*R. E. Thompson.*

Waste Waters As Sources of Raw Materials. A. FOULON. Rundschau deut. Tech. (Ger.) 2:3 ('39). Author discusses progress in recent years in utilization of sewage on land and in recovery of materials from waste waters from mfr. of paper, from coke-oven plants and from carbonization and hydrogenation of brown coal. Effect of sewage in increasing growth on grassland of special importance for supply of feeding stuffs contg. protein. Great progress has been made in reclaiming fibers and fillers from waste waters from mfr. of paper. Up to 50–100 mg. of settleable and suspended solids per l. has been reclaimed in past. New method involving principle of flotation has increased yield from waste waters by 15–20 mg./l. In recovery of phenol from waste waters various solvents used for extension of phenols according to type of waste water being treated. If little phenol present it can first be concd. by adsorption on activated C and then extended with benzene, or, better, with liquid NH_3. In large plants of Emschergenossenschaft 90–95% of phenol in gas liquor recovered as phenol lye for use in prepn. of artificial resins. In recent years avg. of 2200 tons of raw phenol per year recovered at these coke works and 1800 tons of mfd. products produced annually. Amts. of phenol recovered still increasing and in time all requirements of artificial-resin industry may be satisfied from this source. Tritolyl phosphate largely used for extending phenol from waste waters from carbonization and hydrogenation of brown coal, as it is better solvent than C_6H_6 for phenol and cresol.—*C.A.*

From Waste Liquors to War Alcohol. J. R. CALLAHAM. Chem. & Met. Eng. **50**: 12: 104 ('43). Plant built at Thorold, Ont., by Ontario Paper Co., for production of alc. from waste waters from mfr. of paper pulp by sulfite process. Plant designed to produce 600,000 U.S. gal. of 190-proof alc. per yr. but improvements in process have increased production to 800,000 gal. per yr. In production of sulfite pulp for paper mills, wood chips cooked under pressure for 8–10 hr. with soln. of calcium bisulfite; during cooking about half of wood decomposed or dissolved. Ratio of waste liquor to pulp produced is 8–10 to 1 by wt. Liquor contains 10% to 13% solids, including 2% to 4% sugars; it also contains about 2 g. of bound sulfur dioxide and 1 g. of free sulfur dioxide per l., some lime, some methyl alc., and considerable amts. of lignin and other soluble org. compds. not ordinarily fermentable. About 65% of sugars fermentable by ordinary yeast. Plant at Thorold designed to treat 200,000 gpd. of waste liquor. For each ton of pulp produced, 2000 gal. of waste liquor and washings, contg. about 1.6% fermentable sugar, produced; this vol. represents 65% to 70% of total waste liquor. Yield of alc. 18 gal. per ton of pulp produced. If necessary equip. installed to recover all waste liquor, yield of alc. would be increased to about 25 gal. per ton of pulp. Waste liquor flows by gravity to wooden blow pits in which fibers separated from liquor. Recovery of fermentable sugars not complete if concd. liquor alone used; water used for washing pulp therefore added

to increase yield of alc. Liquor screened to remove any remaining fibers and pumped to wooden storage tank. Liquor from blow pits has temp. of 180–190° F.; it passes through heat exchanger in which it is cooled to about 85° F. Cooling water re-used as make-up in pulp mill. Sulfite liquor aerated to remove sulfur dioxide; slurry of slaked lime then added. About 68 lb. of lime added to each 2000 gal. of liquor; pH value of liquor increased by this treatment from 2.5–3.0 to about 6.5. Treated liquor fermented at about 85° F. in wooden fermentation tanks. Active yeast, which has been recovered from previous fermentation, added. Period required for fermentation usually not longer than 20 hr. During fermentation pH value decreases from about 6 to about 5. Carbon dioxide produced during fermentation passed through foam separator, and, after being washed to recover alc., dischgd. to atm. Liquor from bottom of fermentation tanks passes to centrifuge for separation of sludge, which is dischgd. to sewer. Remaining liquor in fermentation tanks allowed to settle for few hours, after which it passes to centrifuge in which yeast separated from liquor. Yeast recovered by "re-use of yeast" process used by Melle works; method increases yield of alc. from given amt. of sugar by about 28%. In Europe 80–90% of yeast recovered by this method, whereas at Thorold almost all yeast recovered. Object of method to separate yeast cells from fermented liquor immediately after fermentation, while they are still active, so that when they are added to fresh wort fermentation begins at once. Liquor from yeast separators mixed with that separated from sludge; mixed liquor, which contains 0.7–1.5% alc., distd. Alc.-water vapor, contg. about 10% alc., introduced at top of still and passes to bottom of rectifying column. Concd. and partially refined ethyl alc., taken from near top of rectifying column, passes to methyl alc. column for final purif. Methyl alc. taken off from top of this column and 192-proof alc. from bottom. Costs of production discussed. Estd. that cost of mfg. alc. from waste sulfite liquor would be 19.75¢/gal. from mill producing 60–80 tons of pulp daily and 12.40¢/gal. from mill producing 200–250 tons of pulp per day. By-products obtained are 2.5–3.5 gal. of methyl alc., 1.0–1.5 gal. of "heads," and 0.2 gal. of fusel oil for every 95 gal. of 190-proof alc. B.O.D. of waste sulfite liquor reduced by 60% during production of alc.; minor changes in process would increase reduction in B.O.D. to 75%. Estd. that amts. of sugar dischgd. annually to streams in U.S. and Canada about 450,000 and 250,000 tons respectively. From these 700,000 tons of sugar 100 mil.gal. of alc. could be obtained. Pulp mill producing 100 tons or more of pulp per day could produce alc. economically at peacetime prices. Now 35 mills in U.S., each mfg. more than 100 tons of pulp daily, which together could produce more than 60 mil.gal. of alc. annually. Production of alc. from mixt. of molasses and sulfite waste liquor would lower cost of production. Waste sulfite liquor contains lignin in amts. up to 4 times the wt. of sugar used for producing alc.; it can be used as raw material for plastics or for impregnating laminated paper. Work in progress in Canada on recovery of lignin, acetic acid, lime and sulfur from sulfite waste liquor.—*W.P.R.*

Acid Recovery From Pickle Liquor. Methods at Recent British Plants. N. SWINDIN. Chem. Tr. J. (Br.) **114**: 465 ('44). Several methods of recovering acid from waste liquor from pickling of iron and steel described. In pickling sheet steel 3 to 4 times as much acid consumed per ton of steel as in other branches of industry; sulfuric acid generally used except where pickling prelim. to galvanizing or enameling. In wire industry, where large amts. of acid also consumed, hydrochloric acid used. In recent expts. in Great Britain, pickling with mixt. of sulfuric and hydrochloric acids at temp. not above 60° C. produced good finish on metal and increased rate of pickling. Methods for recovery of acid from spent pickle liquor usually applied to liquor from use of sulfuric acid alone. Wire, which is to be galvanized or covered with tin or other material, usually pickled in bath contg. 20% hydrochloric acid. When amt. of acid reduced during pickling to 10% or 11%, rate of pickling becomes too low to be economical; liquor then normally dischgd. If, however, amt. of sulfuric acid equiv. to ferrous chloride in spent liquor added, all original hydrochloric acid regenerated. Addn. of sulfuric acid repeated after each pickling until liquor satd. with ferrous sulfate. Slight modification of process enables ferrous sulfate monohydrate to be removed continuously. By using both acids together higher rate of pickling with hydrochloric acid obtained at expense of sulfuric acid, which is cheaper. Mixed ba

can be made up from sulfuric acid and sodium chloride; sodium removed as normal, not as acid sulfate. At Rotherham plant pickling bath contains 10% sulfuric acid by vol. and is used, with addns. of sulfuric acid from time to time as required, until specific gravity of soln. is 1.25. Spent pickle liquor, which has temp. of 70° C., allowed to settle to remove dirt and scale, sulfuric acid added until concn. of acid again 10%, and liquor cooled to 20° C. by water and further cooled to −5° C. with circulating brine. Ferrous sulfate crystallizes out; some water removed as water of crystallization, so that concn. of acid increases to 11% or 12%. Liquor dild. until concn. of acid again 10% and re-used. Amt. of ferrous sulfate in this liquor is 7.5%. At works at Stourport the deLattre process of pickling used and proving satisfactory. Difficult to convert ferrous sulfate to oxide because of large amt. of water of crystallization; this process would be facilitated if ferrous sulfate could be recovered from pickling solns. as monohydrate. A Kestner-Fakler plant for recovery of acid installed at Newport, Mon., in '39 and has proved satisfactory. Suggested that ferrous sulfate should be collected from pickling plants and that it should be roasted at central depot. Recovered acid would be returned to pickling plants.—*W.P.R.*

Plants for Treatment of Waste Waters Containing Acids. H. KEPPNER. Gesundh.-Ing. (Ger.) **62**: 706 ('39). Author gives prelim. outline of proposed stds. for treatment of waste waters contg. H_2SO_4, HCl and HNO_3, or mixt. of these acids, and for design and operation of plant. These waste waters arise mainly from plating and pickling processes in metal industry. Process and plant described designed to neutralize waste waters by addn. of milk of lime.—*C.A.*

Rapid Cementation Methods for Treating Waste Waters Containing Copper. F. SIERP & F. FRÄNSEMEIER. Water. *A Yearbook for Water Chemistry and the Technic of Water Treatment.* **XV** ('41–'42) Verein Deutscher Chemiker. Verlag Chemie, G.m.b.H., (Ger.) ('42) 368 pp. Best method of recovering copper from trade waste waters is rapid cementation process in which copper pptd. by addn. of iron filings. Concn. of copper in waste waters does not affect period required for removal of copper. Contact period of not more than 15 min. sufficient to remove all copper from soln. contg. 250 g./l. (calcd. as $CuSO_4 \cdot 5H_2O$). Copper more easily removed from waters contg. up to 1.5% acid than from less acid waters. With waters contg. large and fluctuating amts. of copper process best carried out in 2 stages. Addn. of freshly pptd. cement copper accelerates process. Oxygen must be excluded if all copper to be removed. When oxygen excluded and sufficient cement copper added, presence of nitric acid and nitrates does not affect process. Several types of plant described and illustrated. Before applying process on large scale, tests should be made in exptl. app. to det. whether complete recovery of copper possible. Use of process in modern plant for pickling metals described.—*W.P.R.*

Treatment and Removal of Waste Waters From Carbonization of Coal. W. BECHER. Gas-u. Wasser. (Ger.) **85**: 459 ('42). Compn. of waste waters from carbonization of brown coal and factors affecting compn. discussed. Methods for removing and recovering phenol surveyed. Where no danger of polg. ground water, waste waters may be allowed to percolate through soil. Limited amts. of such waste water can be disposed of by spraying into furnace of boiler. Methods of treatment of waste waters before dischg. include filtration; aeration (as in Magdeburg P-process); addn. of coagulants, such as salts of iron, aluminum or calcium; oxidation with chems.; and electrolysis. Carbon, peat and coal dust used to adsorb phenols. Methods for recovery of phenols may be divided into those in which by distn. or by introduction of steam into waste waters selective removal and recovery of volatile constituents achieved, and those in which constituents removed from aqueous soln. by adsorption by active carbon or other adsorbents or by extraction with liquid such as benzole. Advantages and disadvantages of distn. and extraction methods discussed. Method chosen for treatment of waste waters from carbonization of brown coal depends upon compn. and concn. of waste waters. Several processes involving distn. or introduction of steam into waste waters described; these include methods of A.-G. Sächsische Werke and Koppers Co. Instead of soln. of sodium hydroxide for absorbing phenols from steam, adsorbents, hydrocarbons and solvents with high boiling points, such as coal-tar oil, have been used. Wiegmann claims that soln. of phenol by solvent such as coal-tar oil has disadvantages,

that acids not removed from waste waters and that, when solvent regenerated with sodium hydroxide, completely satd. phenolate lye obtained. Satisfactory purif. of waste waters can be obtained by using silica gel, activated carbon or org. exchange materials, such as Wofatit, as adsorbents. These substances have certain selective action but selection not so great that inorg. and org. constituents can be separated by series of filters contg. different adsorbents. Because of variety of substances adsorbed regeneration of adsorbent difficult. Relatively rapid partial inactivation of adsorbent appears to be unavoidable because inorg. sulfur compds. and other substances in waste waters react in filters, and possibly with adsorbent itself, to form insol. products. Of methods involving extraction of phenols by liquid only 3 used on large scale: extraction by benzole, by tricresylphosphate and by "Phenosolvan." Oldest method of extraction with liquid with boiling point lower than those of phenols was that used by Emschergenossenschaft, in which benzole used. Deg. of extraction of phenols not satisfactory in this method and recovery of benzole difficult. Large amts. of benzole required and even if aniline or quinoline added to increase amt. of phenol extracted, method remains uneconomic because of high price of addnl. solvents. Soly. of phenol in other solvents with low boiling points discussed. Phenosolvan process described and illustrated. Eff. of process increased if phenol content of waste waters from distn. of brown coal increased by addn. of phenols from tar oil before waste waters pass into plant for removing phenol. Extraction of phenols with solvents having boiling points higher than those of phenols has been used; substances employed either tar acids with boiling points above 230° C. or homologs of phenol such as tri- and tetra-alkyl- or aryl-phenols. Tar acids and homologs of phenol should absorb 25–30% by wt. of phenol, so that by using 5% soln. of solvent and extracting in 2 or 3 stages, satisfactory recovery of phenol should be attained. Other substances proposed as solvents for phenols are tar oils with boiling points between 230° and 375° C., hydrogenated tar products with boiling points between 200° and 350° C., hydrocarbons and mineral oils. In all methods depending on extraction of phenols qual. of either phenolic oils or of solvent, or of both, becomes greatly reduced by presence of less valuable org. substances. Hager has overcome this disadvantage by using as solvent wash oil used for stripping benzole from coal gas; phenols recovered from wash oil by distn. and absorbed by sodium hydroxide. Use of tricresylphosphate for extraction of phenol described. This method satisfactory for treating waste waters which give residues on evapn. of 1 to 2 g./l.; not satisfactory for treating waste waters which give residues on evapn. of 15 to 20 g./l., mainly because tricresylphosphate becomes rapidly pold. Substances other than phenols readily extracted by tricresylphosphate. With continual regeneration of tricresylphosphate these substances form resin-like or asphalt-like compds. of high mol. wt., which cause emulsions to form, reduce eff. and increase loss of tricresylphosphate. Methods have been proposed for preventing emulsification, among which is addn. of activated carbon to waste waters. For small plants extraction methods preferable to distn.; for large plants distn. alone or combination of both types of method may be economical.—*W.P.R.*